Electronic Atlas of Parasitology

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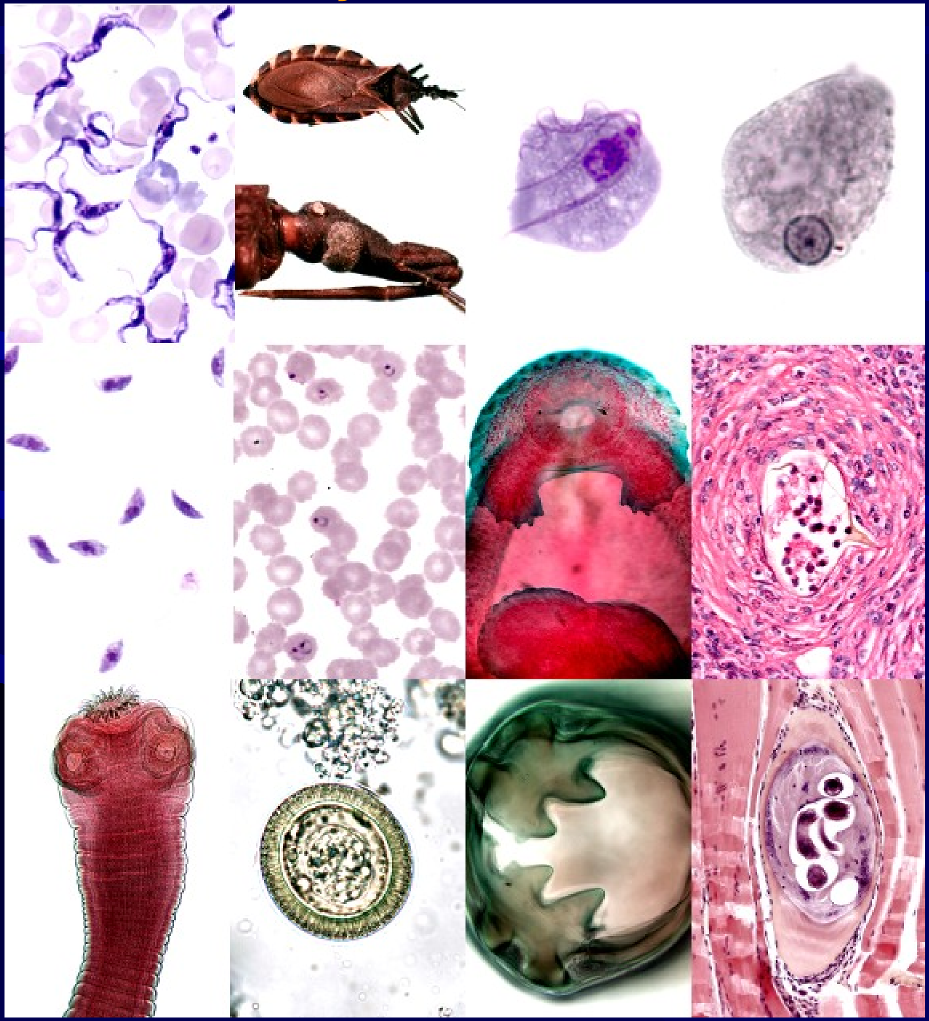

Version 2.0

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1. Blood & Tissue Flagellates

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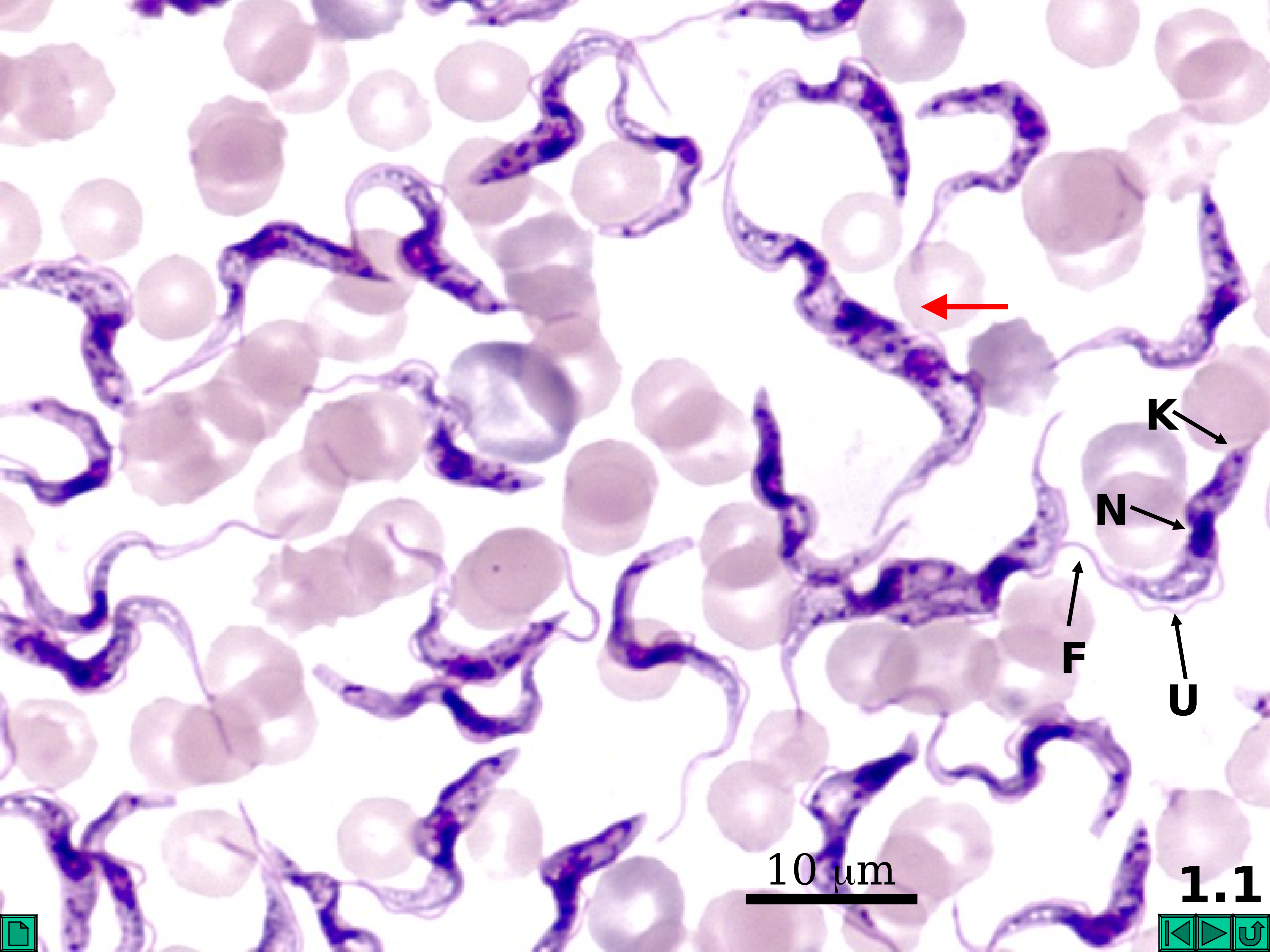
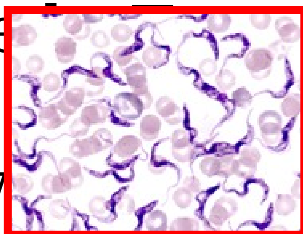
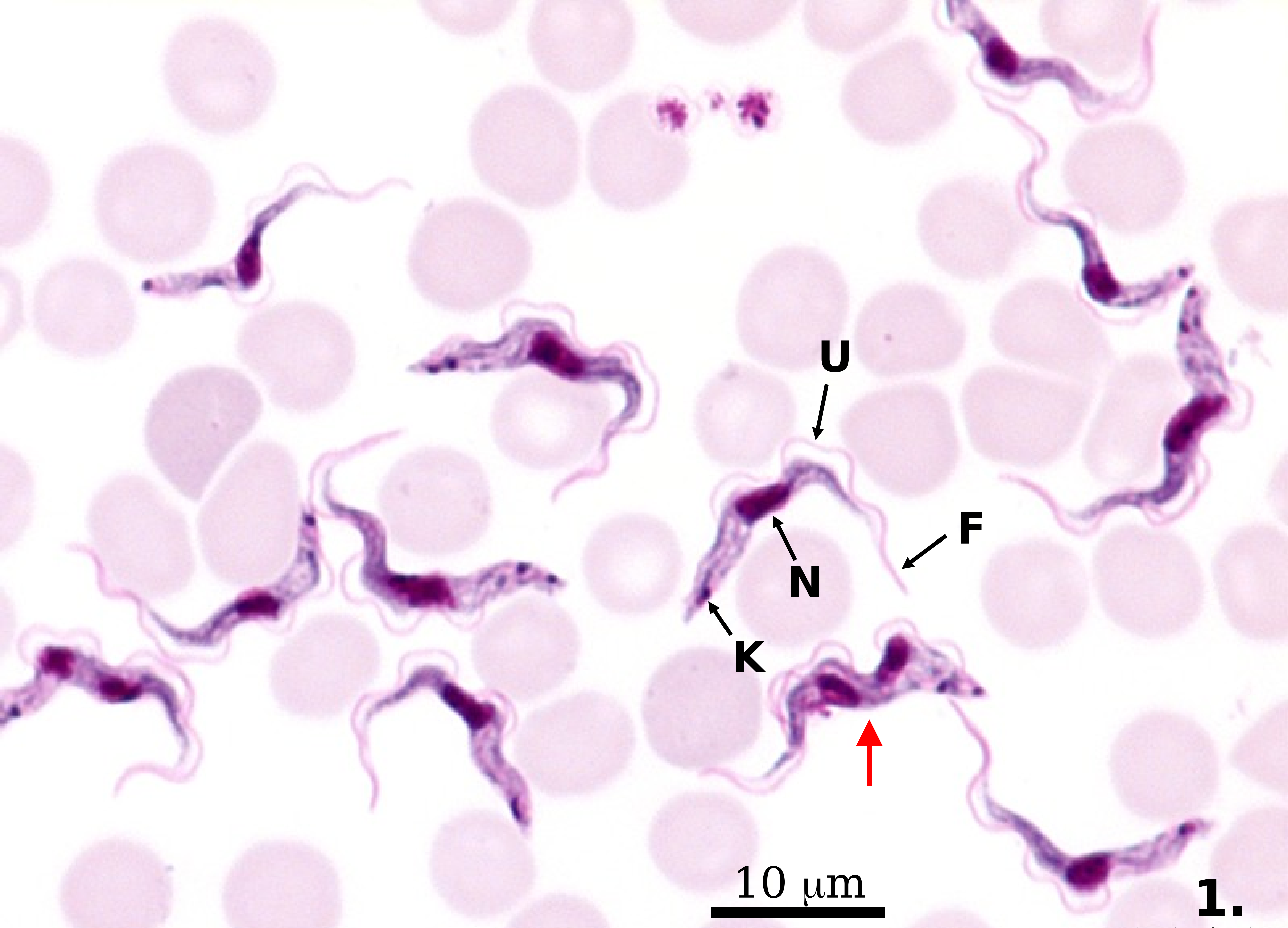


1.1

1.1 Trypomastigotes of *Trypanosoma brucei rhodesiense,* peripheral blood smear. Note the undulating membrane (U), anterior flagellum (F), and posterior location of the kinetoplast (K) relative to the nucleus (N). These would be indistinguishable from trypomastigotes of *T. b. gambiense*. The long slender form of trypomastigote is the dividing form (red arrow), whereas the short, stumpy form (not shown) is infective for the intermediate host. *T. b. rhodesiense* is transmitted by the tsetse fly, *Glossina morsitans, G. pallidipes,* and *G. tachinoides,* in the savannah regions of east Africa. Numerous wild game animals serve as reservoir hosts. This parasite is highly pathogenic for humans, causing 100% mortality unless treate

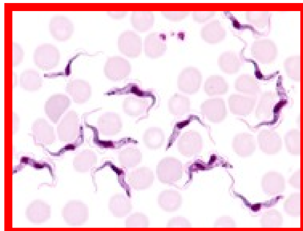
b. rhodesiense typically does not cause the symptoms of African sleeping sickness seen w

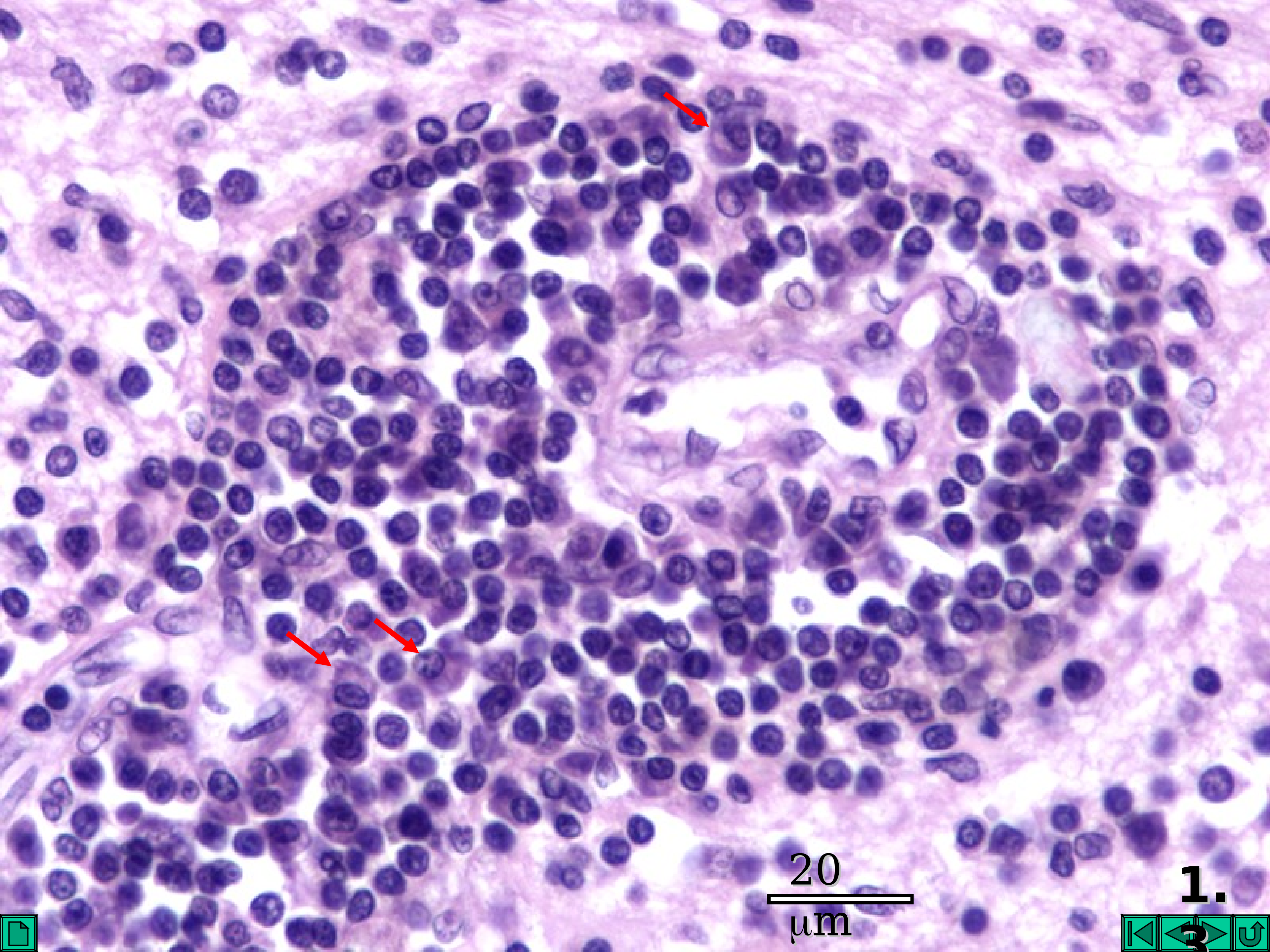




1.

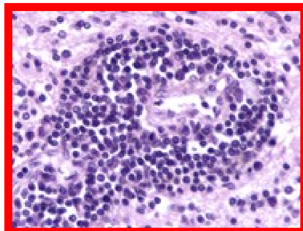
1.2 Trypomastigotes of *Trypanosoma brucei gambiense,* peripheral blood smear. Note the free flagellum (F), undulating membrane (U), and posterior location of the kinetoplast (K) relative to the nucleus (N). These would be indistinguishable from trypomastigotes of *T. b. rhodesiense*. The long slender form of trypomastigote is the dividing form (red arrow), whereas the short, stumpy form (not shown) is infective for the intermediate host. *T. b. gambiense* is transmitted by the tsetse fly, *Glossina palpalis* and *G. tachinoides,* in riverine regions of west and central Africa. There are no reservoir hosts. This species causes immune-mediated damage to capillaries in the brain (perivascular cuffing), resulting in African sleeping sickness and, if untreated, death.

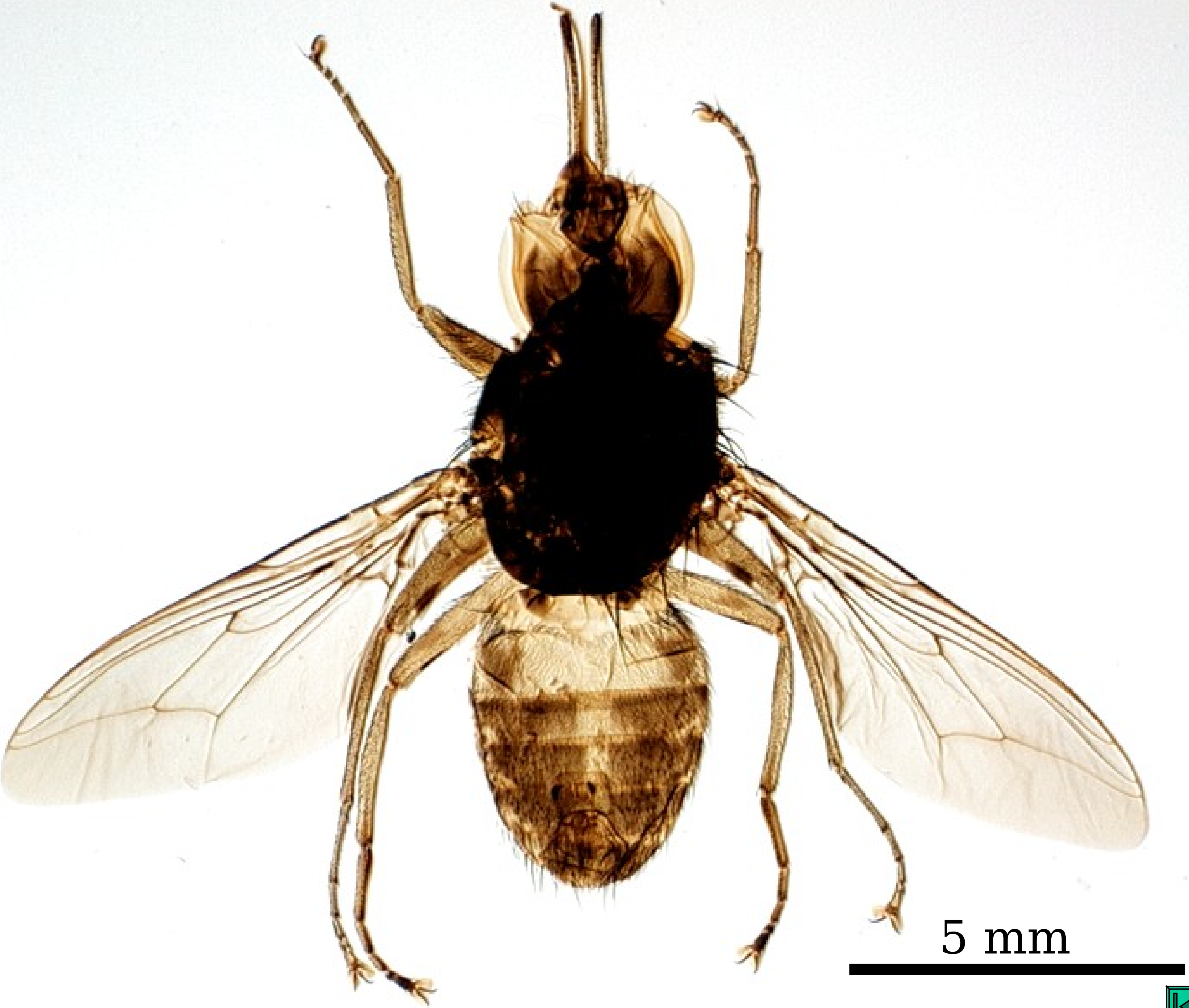



20
µm

1.3 African trypanosomiasis in a histological section of brain. Note the accumulation of inflammatory cells around the periphery of the blood vessel (perivascular cuffing), including numerous plasma cells (arrows). This phenomenon may be indicative of a hypersensitivity response against parasite antigens adsorbed onto endothelial cells of blood vessels. The resulting immune-mediated damage to the endothelium results in seepage of fluid from the blood into the brain (cerebral edema), leading to neurological symptoms. No trypomastigotes are visible in this section.

- back to *Trypanosoma b. gambiense*

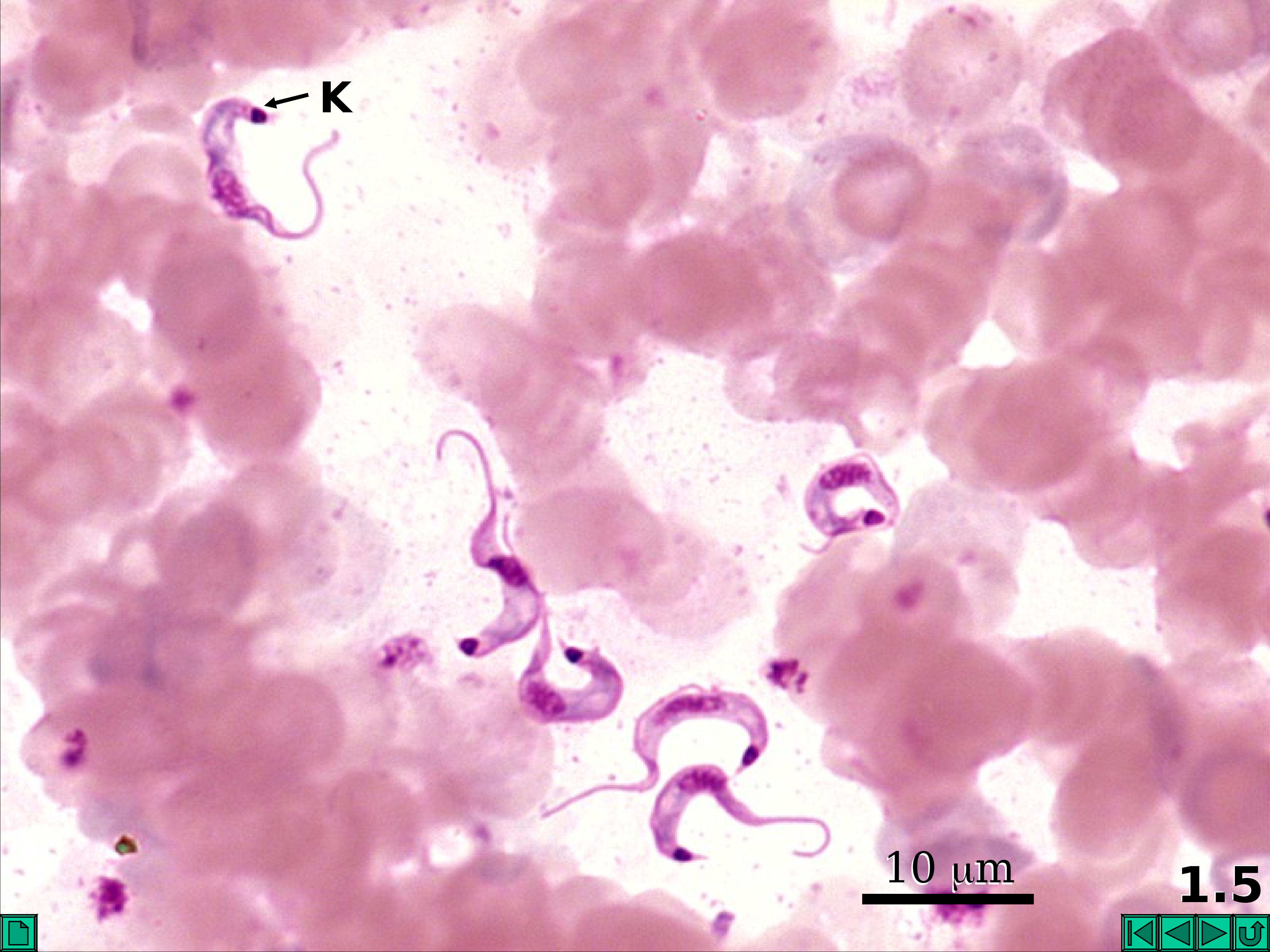




1.

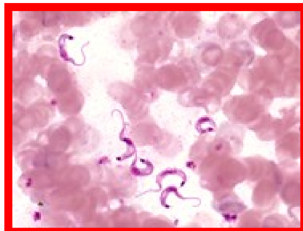
1.4 *Glossina* sp. (tsetse fly), the vector of African trypanosomiasis due to *Trypanosoma brucei brucei* in animals, and *T. b. gambiense* and *T. b. rhodesiense* in humans. The wings, which are extended outward on this mounted specimen, normally are folded on top of each other when resting. Although most flies are not susceptible to infection, both males and females can serve as vectors.

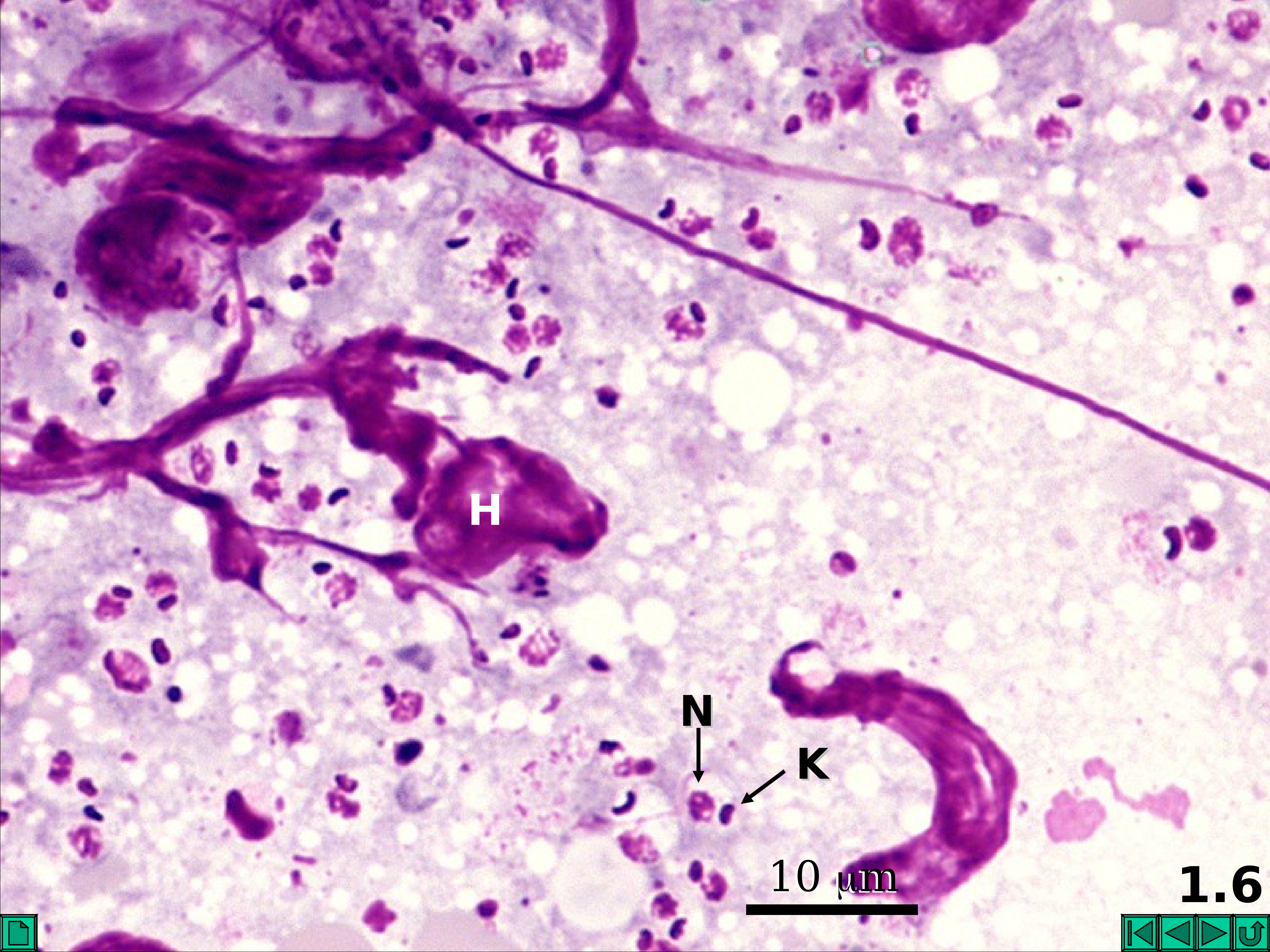
- back to *Trypanosoma b. rhodesiense*
- back to *Trypanosoma b. gambiense*



1.5

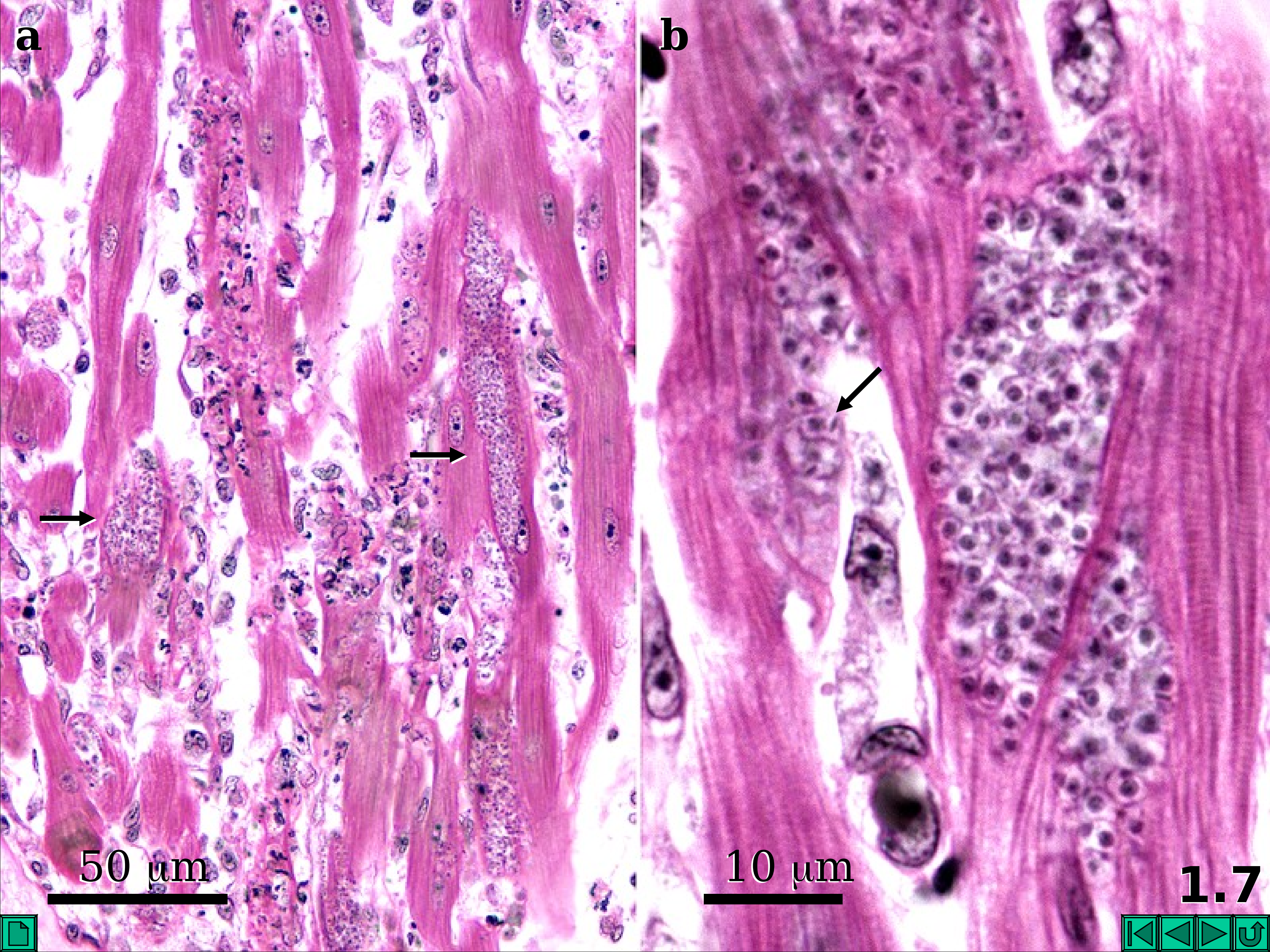
1.5 Trypomastigotes of *Trypanosoma cruzi,* peripheral blood smear. Note the posterior location and large size of the kinetoplast (K), and the characteristic “C”-shape of several cells. The trypomastigote of this species is nondividing, and serves instead to disseminate the infection to tissue cells and to the vector. *T. cruzi* is transmitted in South and Central, and rarely North, America by several species of kissing bugs. Numerous wild and peridomestic animals (e.g., dogs and cats) serve as reservoir hosts. This parasite causes Chagas’ disease, which has both an acute stage, sometimes fatal in young children, and a chronic stage, which includes a gastrointestinal form (megaesophagus and megacolon, due to destruction of autonomic ganglia) and a cardiac form (cardiomegaly, ventricular aneurism, and arrhythmia, due to





1.6

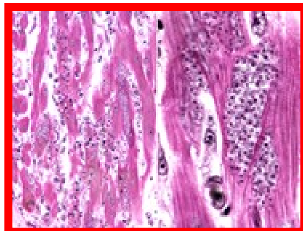
1.6 Amastigotes of *Trypanosoma cruzi,* spleen smear. Note the absence of an undulating membrane or emergent flagellum. The kinetoplast (K) is more darkly stained than the nucleus (N). Large purple objects are host spleen cell nuclei (H). Amastigotes of *T. cruzi* would be indistinguishable from those of *Leishmania donovani*.

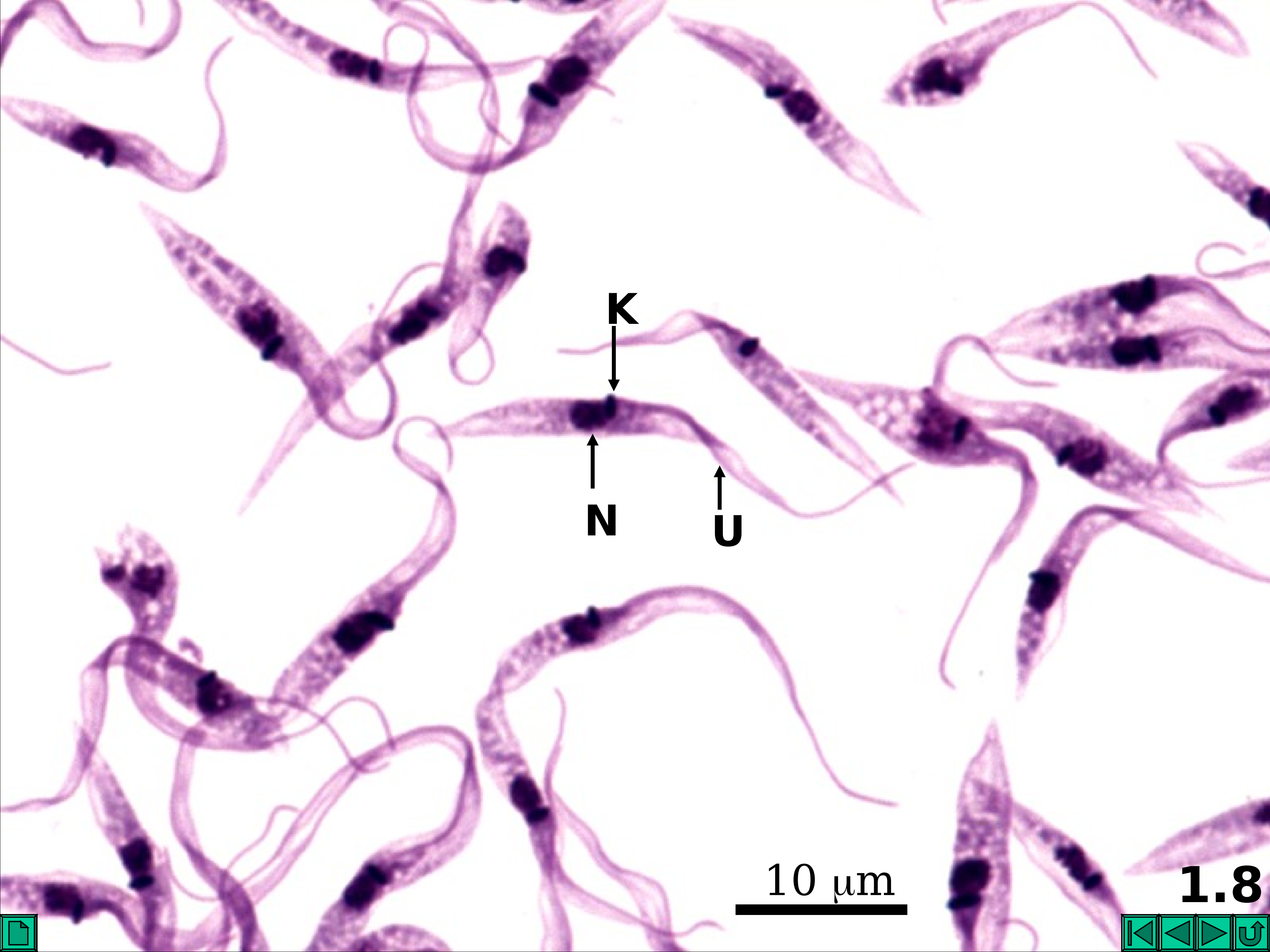

a
b
50 µm
10 µm

1.7

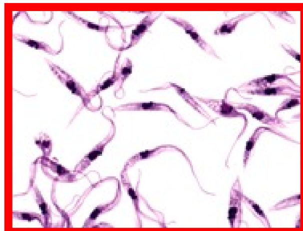
1.7 Amastigotes of *Trypanosoma cruzi* in heart muscle cells, histological section. **a.** Low magnification view, showing several infected cells (arrows) and a central necrotic region. **b.** Higher magnification, showing amastigotes packed within cells. A nucleus and kinetoplast are visible in some amastigotes (arrow). Due to the destruction of myofibers and conducting cells of the heart, this parasite is the leading cause of heart disease in S. America.

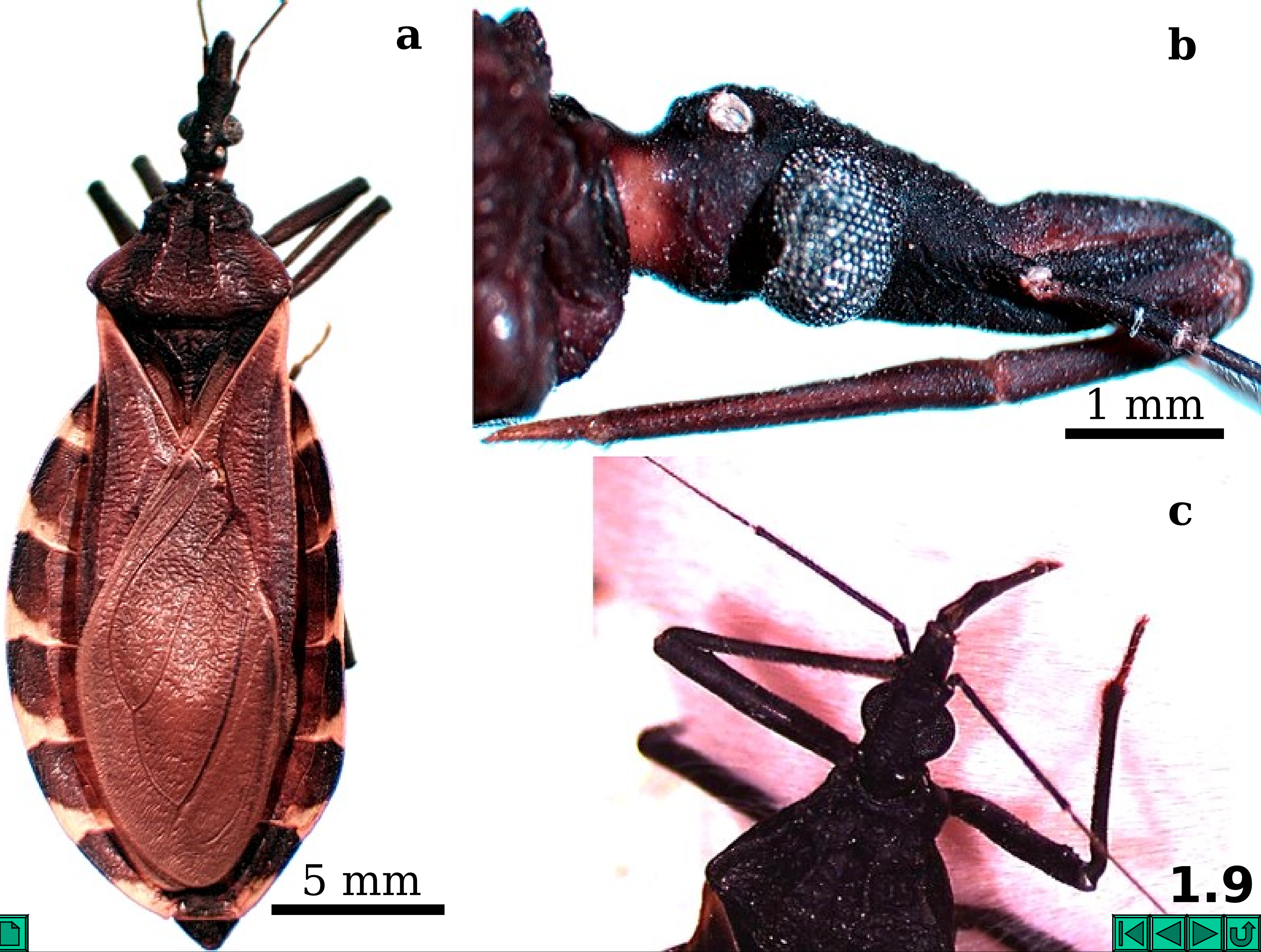
- back to trypomastigote of *Trypanosoma cruzi*




K
N
U
10 μm

1.8 Epimastigotes of *Trypanosoma cruzi,* culture smear ("crithidial" form). This is the replicating stage found in the gut of the kissing bug. Note the undulating membrane (U) and anterior location of the kinetoplast (K) relative to the nucleus (N). These are indistinguishable from epimastigotes of other trypanosomes.





1.9

1.9 Kissing bug, *Triatoma gerstaeckeri* (Family Reduviidae, Subfamily Triatominae), a potential vector of *Trypanosoma cruzi*. **a.** Entire bug viewed from above. **b.** Side view of head, showing proboscis folded underneath. **c.** Bug feeding on a mouse. Note the extended proboscis. In addition to its large size, other features of this vector include a cone-shaped head with prominent eyes, dorsoventrally flattened body with wings folded in a concavity on top of the abdomen, margin of the abdomen with orange stripes, antennae in 4 segments, and a 3-segmented labial tube. Infectious metacyclic trypomastigotes of *T. cruzi* pass out in the bug's feces, and are rubbed into the bite wound or the eye, usually while the victim is sleeping. This specimen was collecte

San Antonio, TX.

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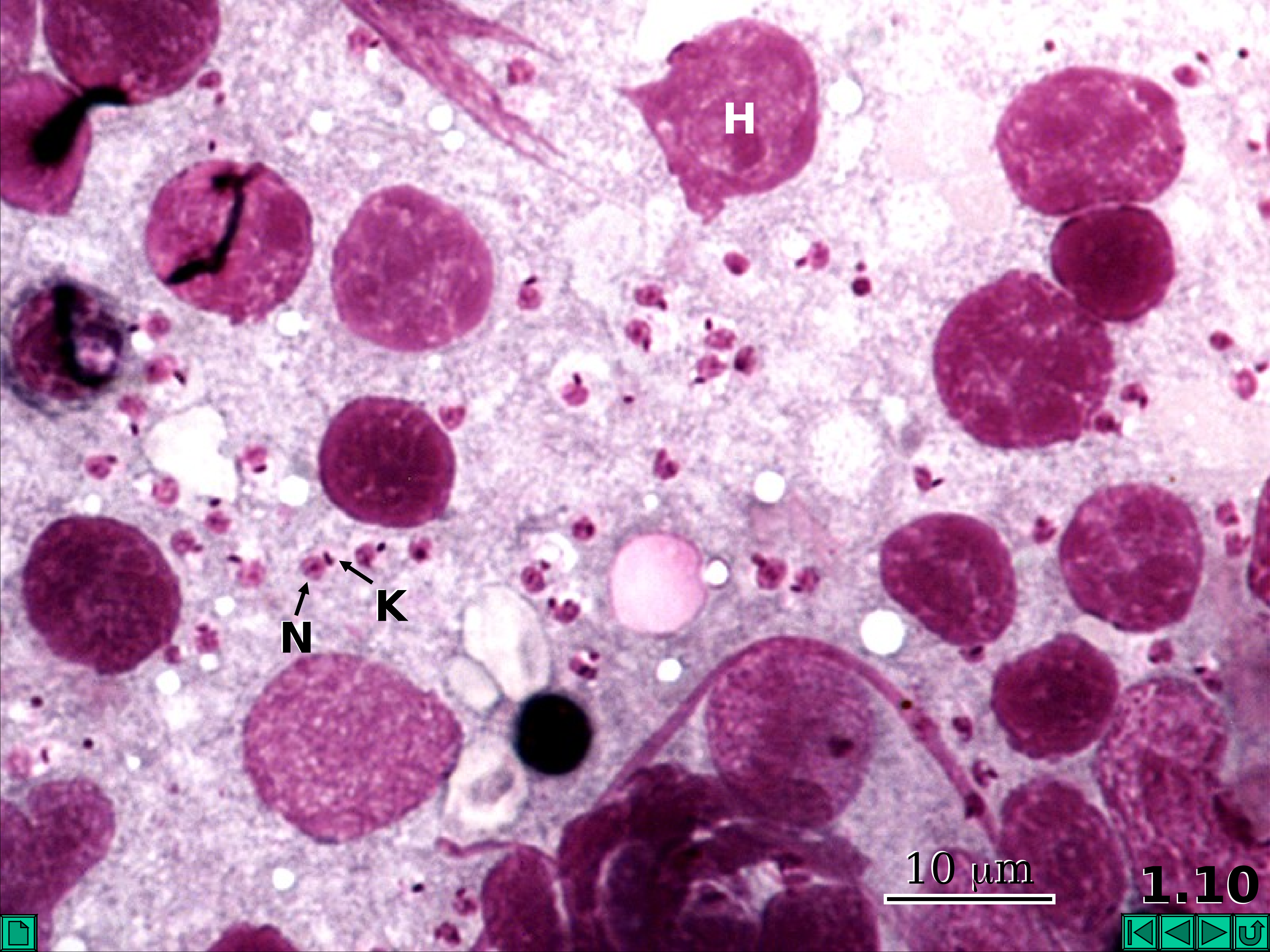
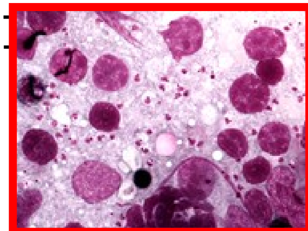
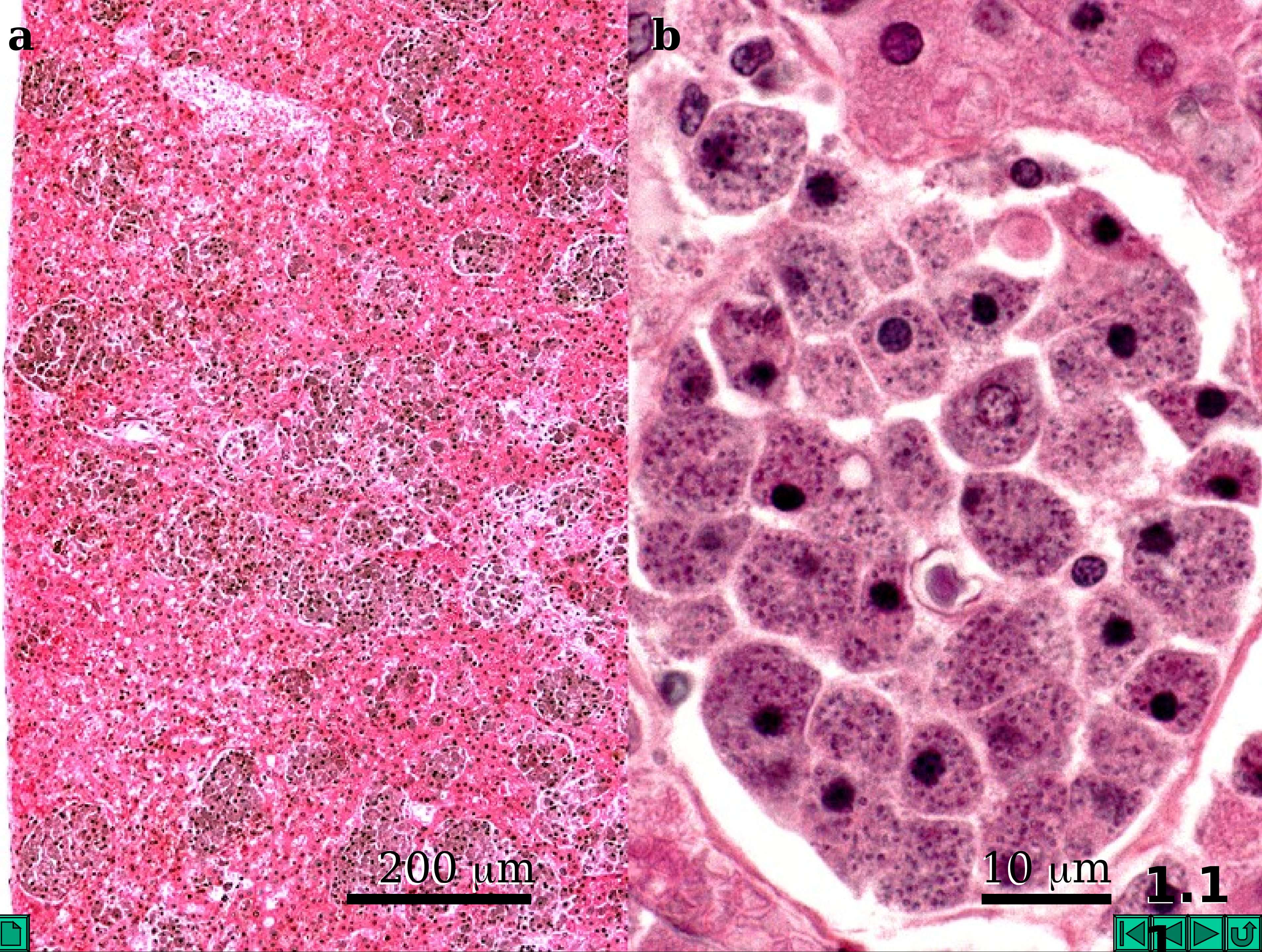
- back to trypomastigote of *Trypanosoma cruzi*
- back to epimastigote of



1.10

1.10 Amastigotes of *Leishmania donovani,* liver smear. These are indistinguishable from amastigotes of *Trypanosoma cruzi*. Note the minute size, and absence of an emergent flagellum or undulating membrane. The kinetoplast (K) is the dark rod-shaped inclusion near the round nucleus (N). Large purple structures are host liver cell nuclei (H). *L. donovani* is transmitted by *Phlebotomus* spp. sand flies in the old world (Africa, Asia, Middle East) and by *Lutzomyia* spp. in the new world (C and S America). Dogs and rodents are important reservoir hosts. Amastigotes of *L. tropica* or *L. mexicana* from skin lesions and *L. braziliensis* from mucocutaneous lesions would appear identical. Amastigotes of *L. donovani* infect macrophages of internal orga and cause visceral leishmaniasis (kala azar), characterized by hepatosplenomegaly,

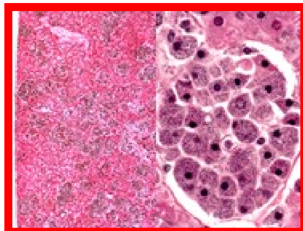


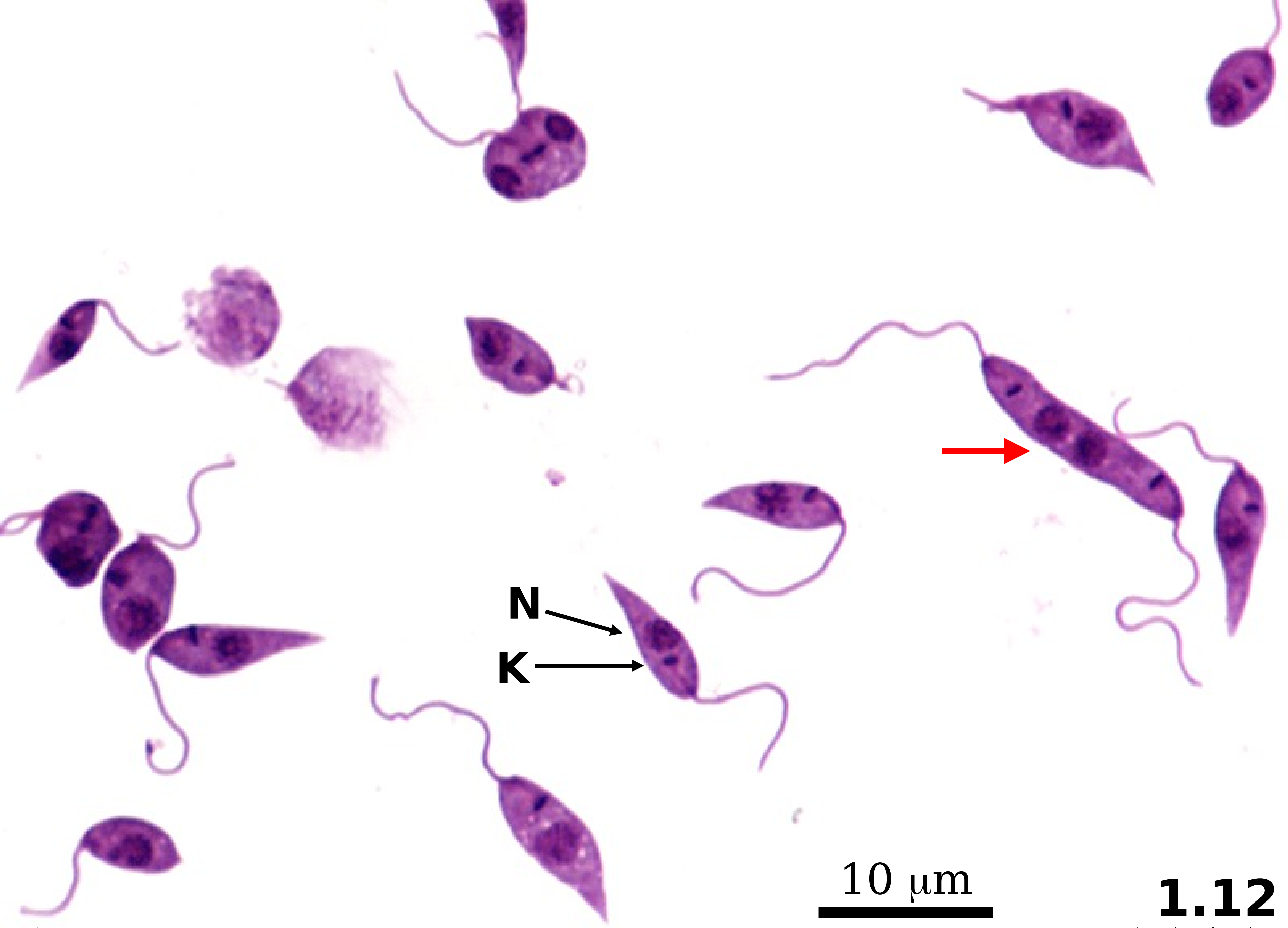

a
b
200 μm
10 μm

1.1

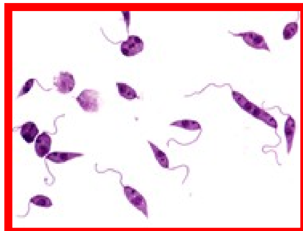
1.11 Visceral leishmaniasis in liver caused by *Leishmania donovani*, histological section. **a.** Low magnification view, showing extensive infection of liver macrophages (Kupffer cells) by amastigotes, apparent as dark, mottled areas. **b.** Higher magnification, showing infected host cells filled with amastigotes.

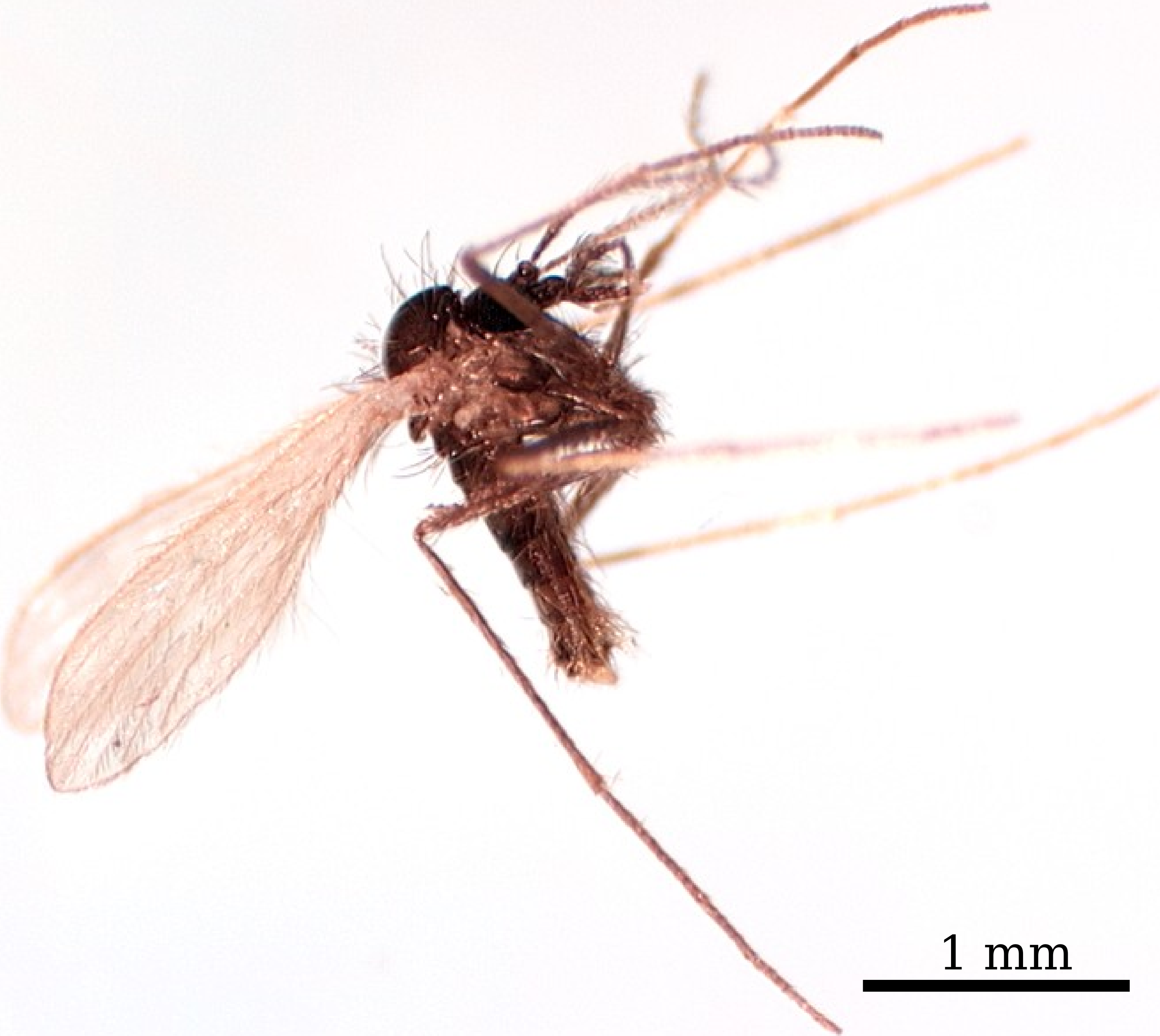
- back to amastigote of *Leishmania donovani*




N
K
10 μm

1.12 Promastigotes of *Leishmania donovani*, culture smear ("leptomonad" form). This is the replicating stage found in the gut of the sand fly. Note the absence of an undulating membrane, and the anterior location of the kinetoplast (K) relative to the nucleus (N). Dividing stages (red arrow) are visible.





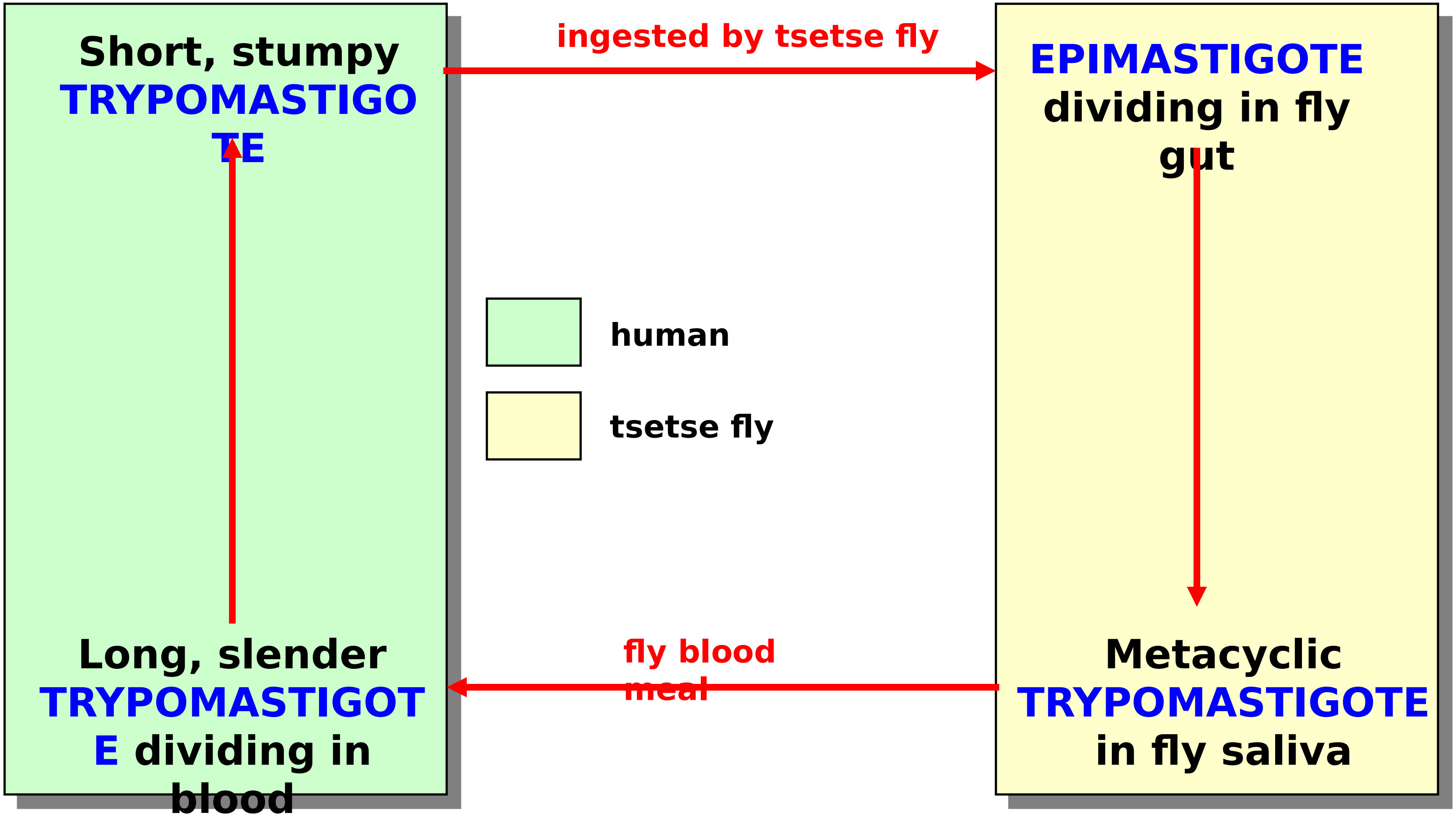
1.1

1.13 Female *Lutzomyia diabolica* (sand fly), a potential vector of *Leishmania mexicana* in the New World. In addition to its small size, the sand fly can be recognized by its hairy wings and body, and the 60-degree angle at which the resting wings are held from the body. This insect possesses cutting rather than piercing mouthparts.

- back to amastigote of *Leishmania donovani*

- back to promastigote of *Leishmania donovani*

Life cycle of *Trypanosoma brucei*



Short, stumpy TRYPOMASTIGOTE

ingested by tsetse fly

EPIMASTIGOTE dividing in fly gut

Metacyclic TRYPOMASTIGOTE in fly saliva

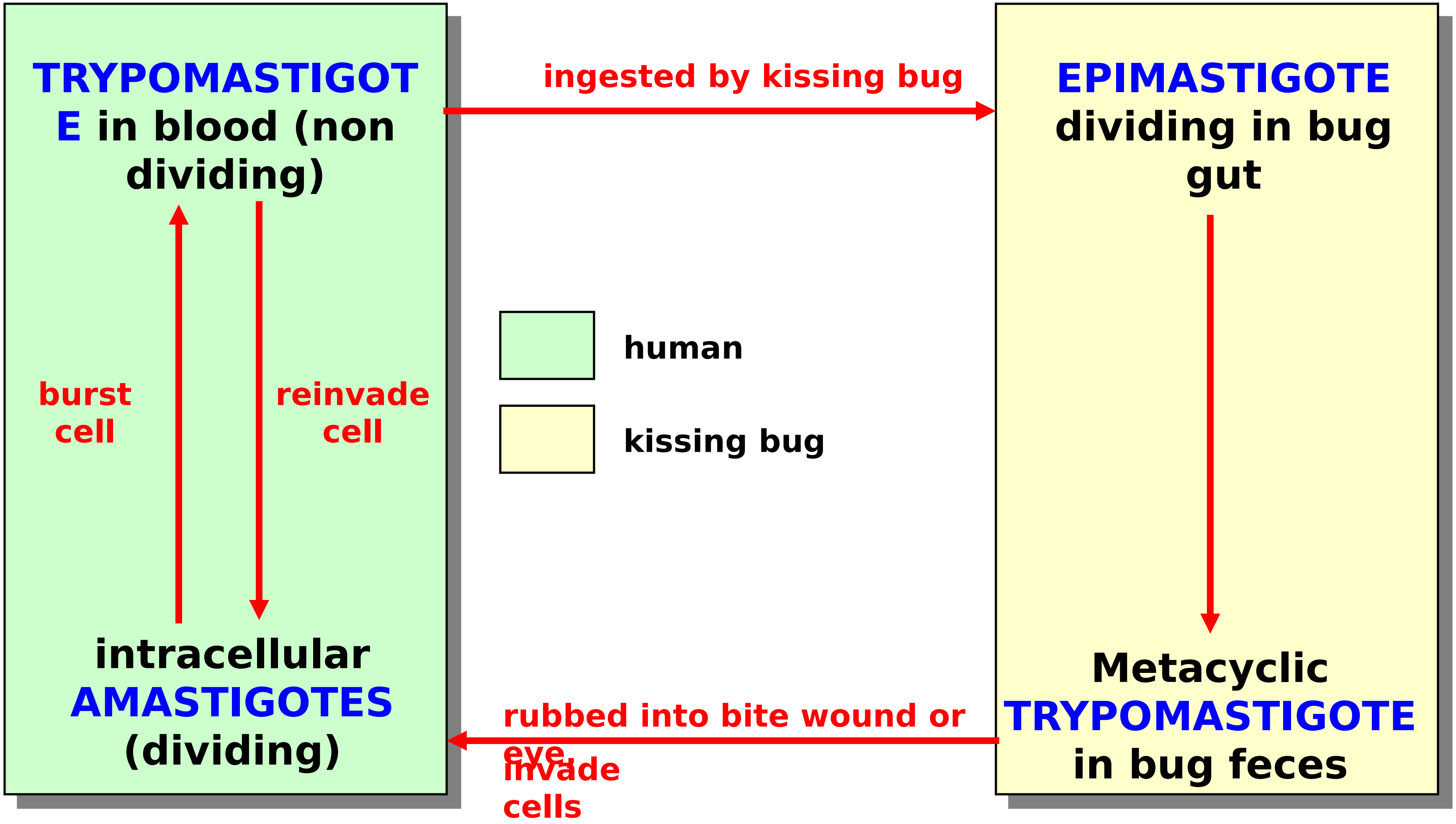
fly blood meal

Long, slender TRYPOMASTIGOTE dividing in blood

🟩 human

🟨 tsetse fly

Life cycle of *Trypanosoma cruzi*



TRYPOMASTIGOTE in blood (non dividing)

burst cell

reinvade cell

intracellular AMASTIGOTES (dividing)

ingested by kissing bug

EPIMASTIGOTE dividing in bug gut

Metacyclic TRYPOMASTIGOTE in bug feces

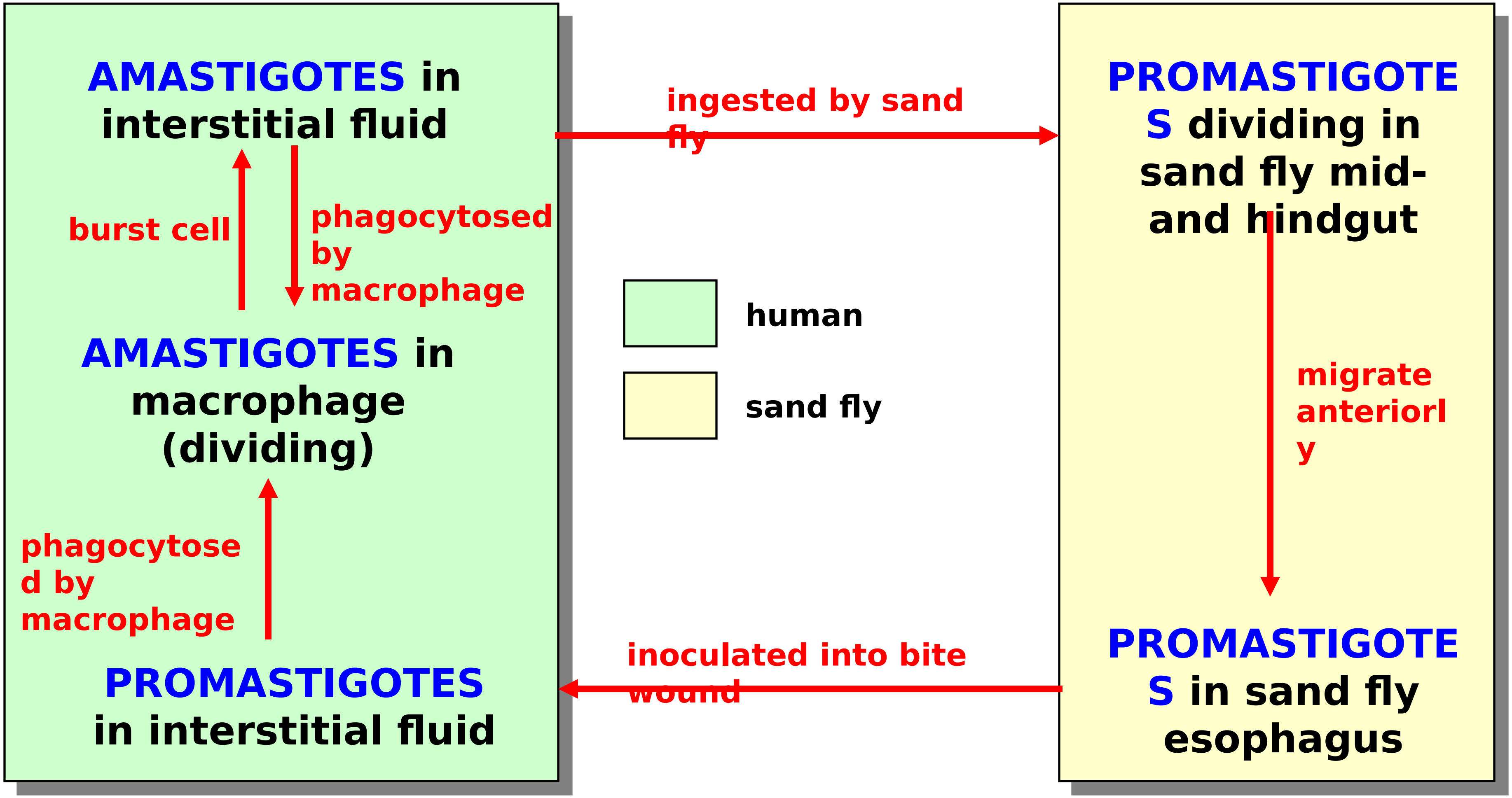
rubbed into bite wound or eye

invade cells

🟩 **human**

🟨 **kissing bug**

Life cycle of *Leishmania* spp.



AMASTIGOTES in interstitial fluid

burst cell

phagocytosed by macrophage

AMASTIGOTES in macrophage (dividing)

phagocytosed by macrophage

PROMASTIGOTES in interstitial fluid

ingested by sand fly

PROMASTIGOTES dividing in sand fly mid- and hindgut

migrate anteriorly

PROMASTIGOTES in sand fly esophagus

inoculated into bite wound

🟩 human

🟨 sand fly

2. Lumen-Dwelling Flagellates

- Trophozoites of *Chilomastix mesnili*
- Cysts of *Chilomastix mesnili*
- Trophozoites of *Giardia lamblia*
- Cysts of *Giardia lamblia*
- Trophozoites of *Dientamoeba fragilis*
- Trophozoites of *Pentatrichomonas hominis*
- Trophozoites of *Trichomonas vaginalis*

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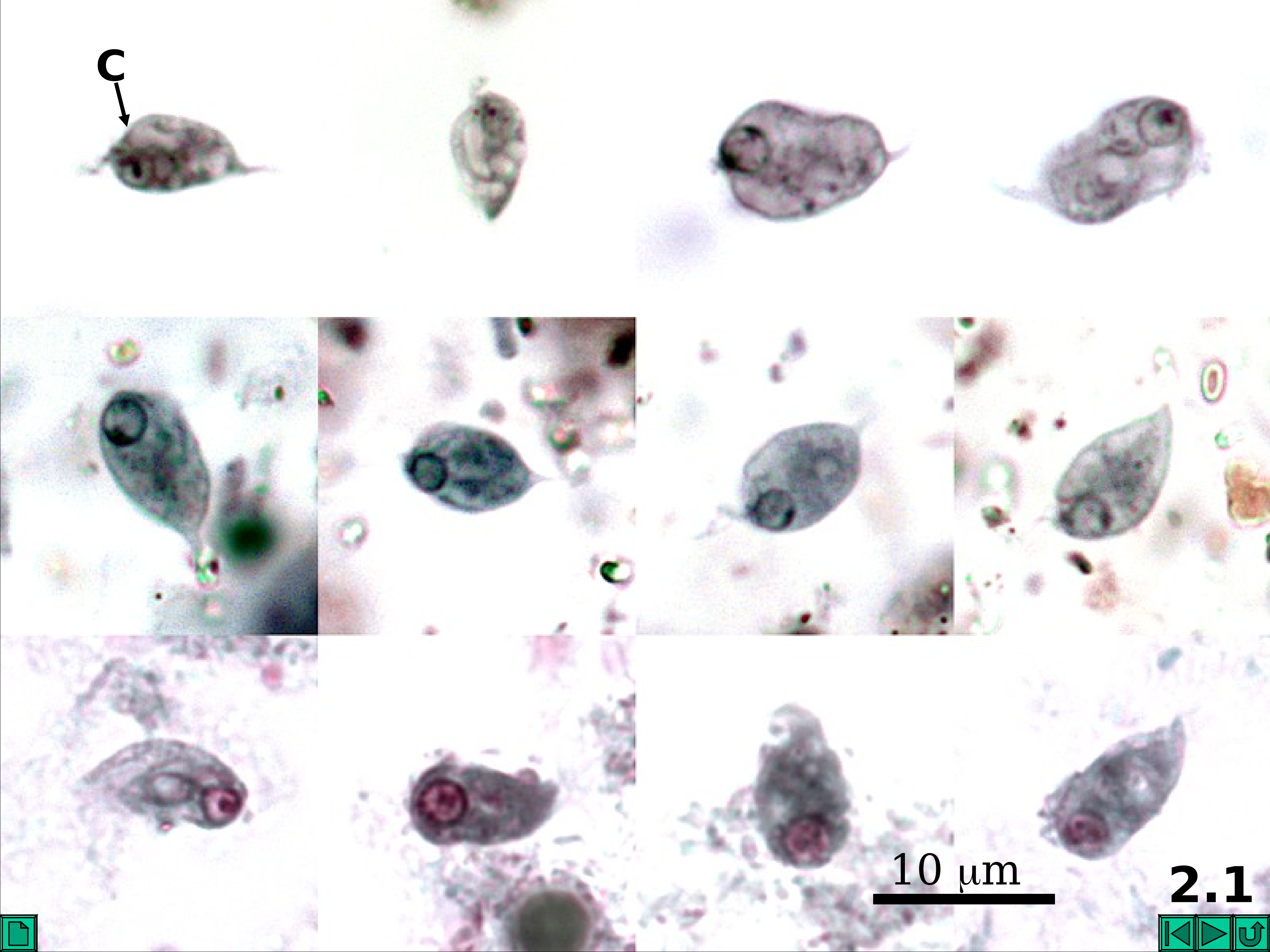
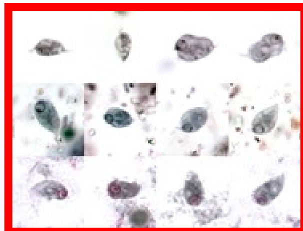
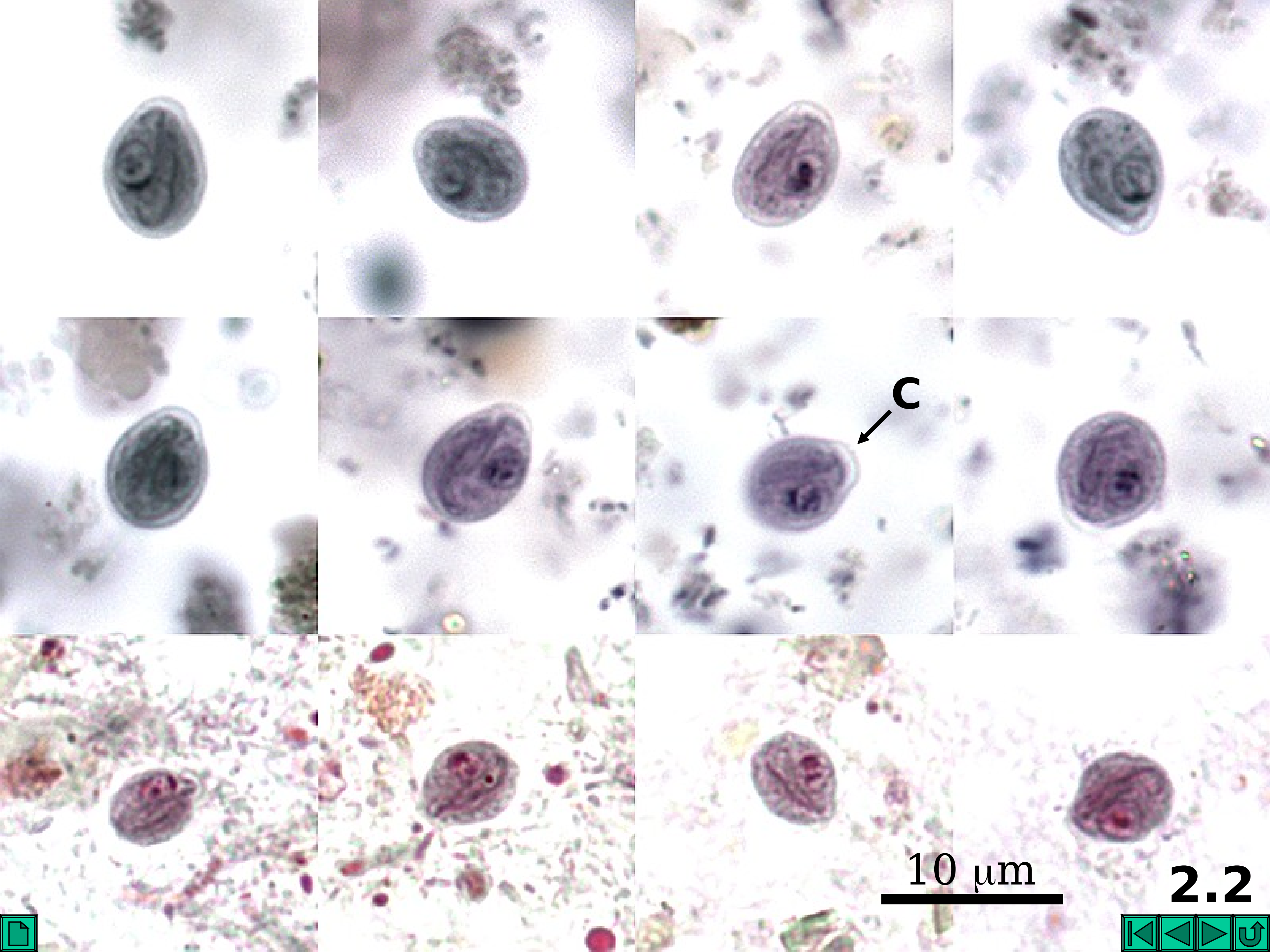


2.1

2.1 Trophozoites of *Chilomastix mesnili,* stool smear. Note the pyriform shape, single nucleus, and presence of a cytostomal groove (C). There are three anteriorly directed flagella, and one flagellum that is recurved into the cytostomal groove. Note also the considerable size variation. Infection is contracted by ingesting the cyst. Although usually considered harmless, some authorities suspect that it may cause diarrhea. The trophozoite would be found mainly in loose stools. Top 2 rows, hematoxylin stain; bottom row, trichrome stain.

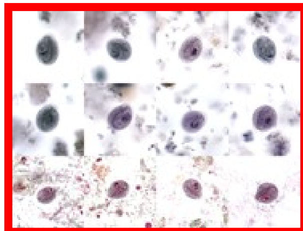


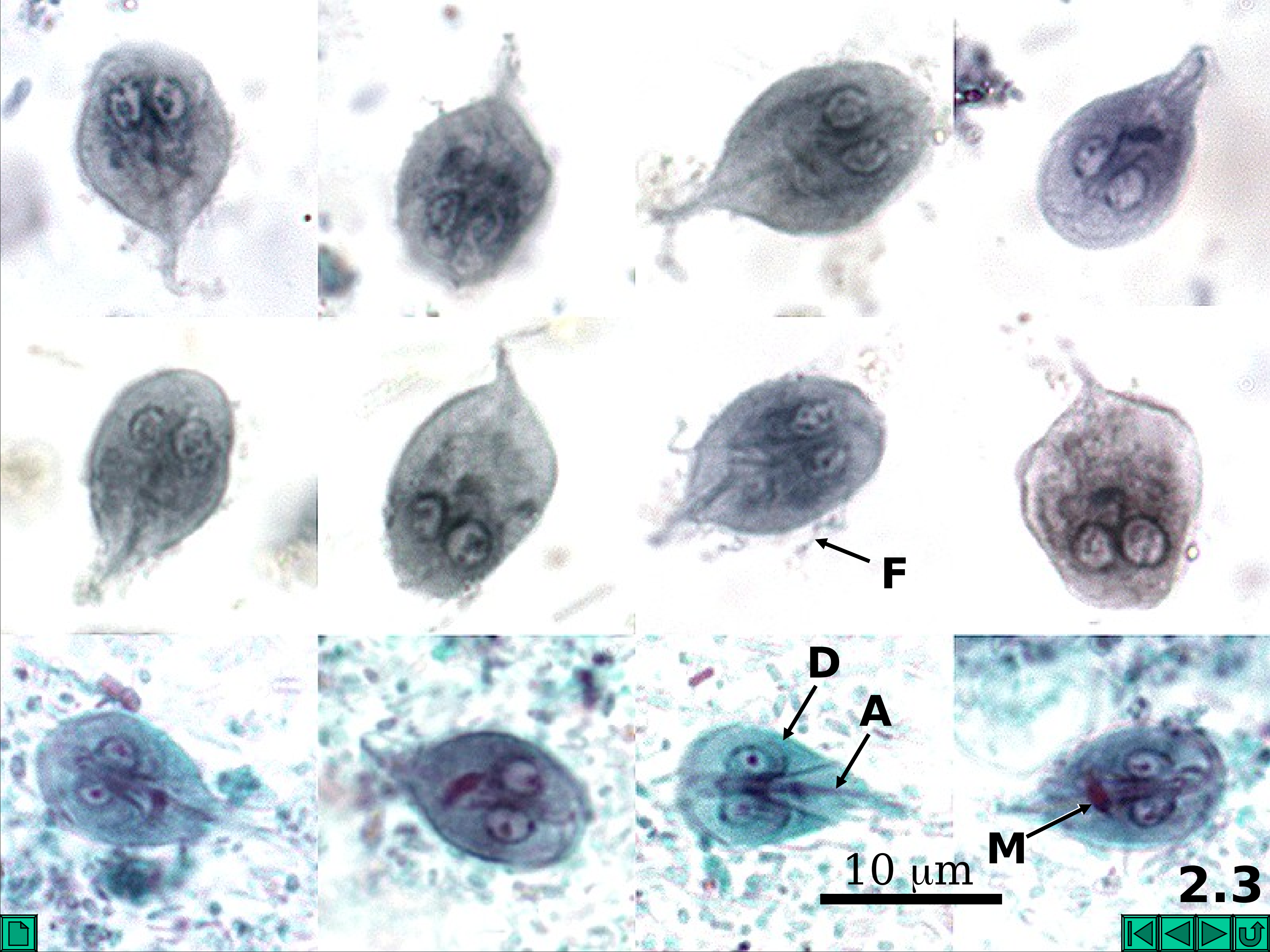


2.2

2.2 Cysts of *Chilomastix mesnili,* stool smear. Note the lemon shape, single nucleus, and “cap” at one end (C). Axonemes and the cytostomal groove often can be seen within the cyst. This stage normally would be found in solid stools, and is the infective form. Top 2 rows, hematoxylin stain; bottom row, trichrome stain.

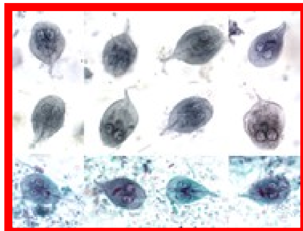
- back to trophozoite of *Chilomastix mesnili*

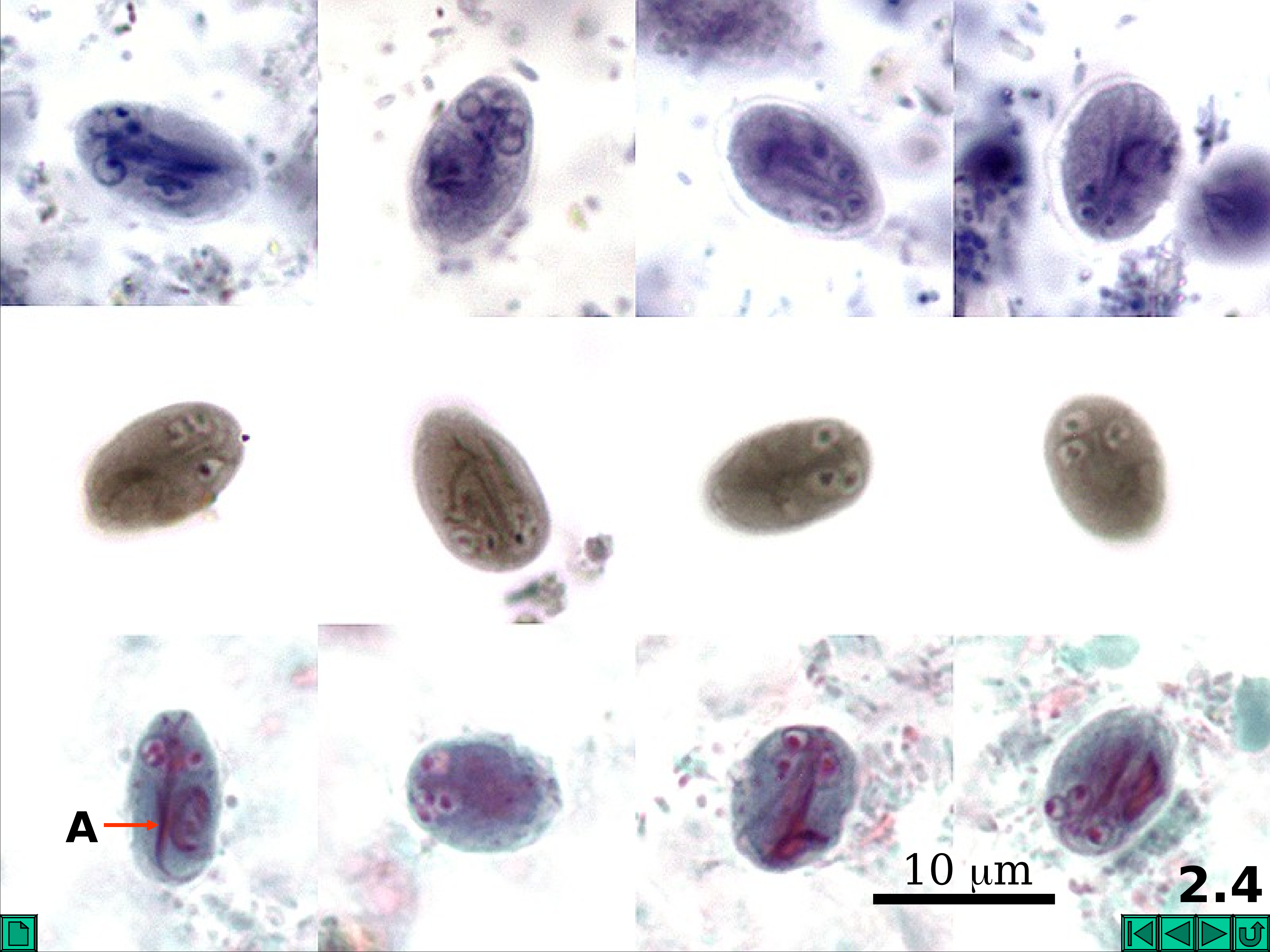



F
D
A
10 µm
M

2.3 Trophozoites of *Giardia lamblia,* stool smear. Note the pyriform shape, two nuclei, and median bodies (M). The trophozoite stage normally would be found in loose stools. Flagella (F, which number 8) are not visible in all photographs. Axonemes (A) can be seen in the cytoplasm of some cells as dark lines. The trophozoite attaches to the surface of intestinal epithelial cells by its adhesive disk (D). Infection is contracted by ingesting the cyst. While many infected people are asymptomatic, this flagellate can cause protracted diarrhea. Top 2 rows, hematoxylin stain; bottom row, trichrome stain.

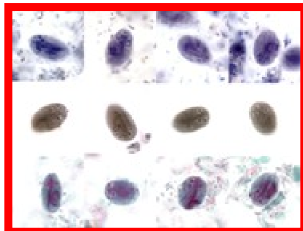
- back to microsporidian

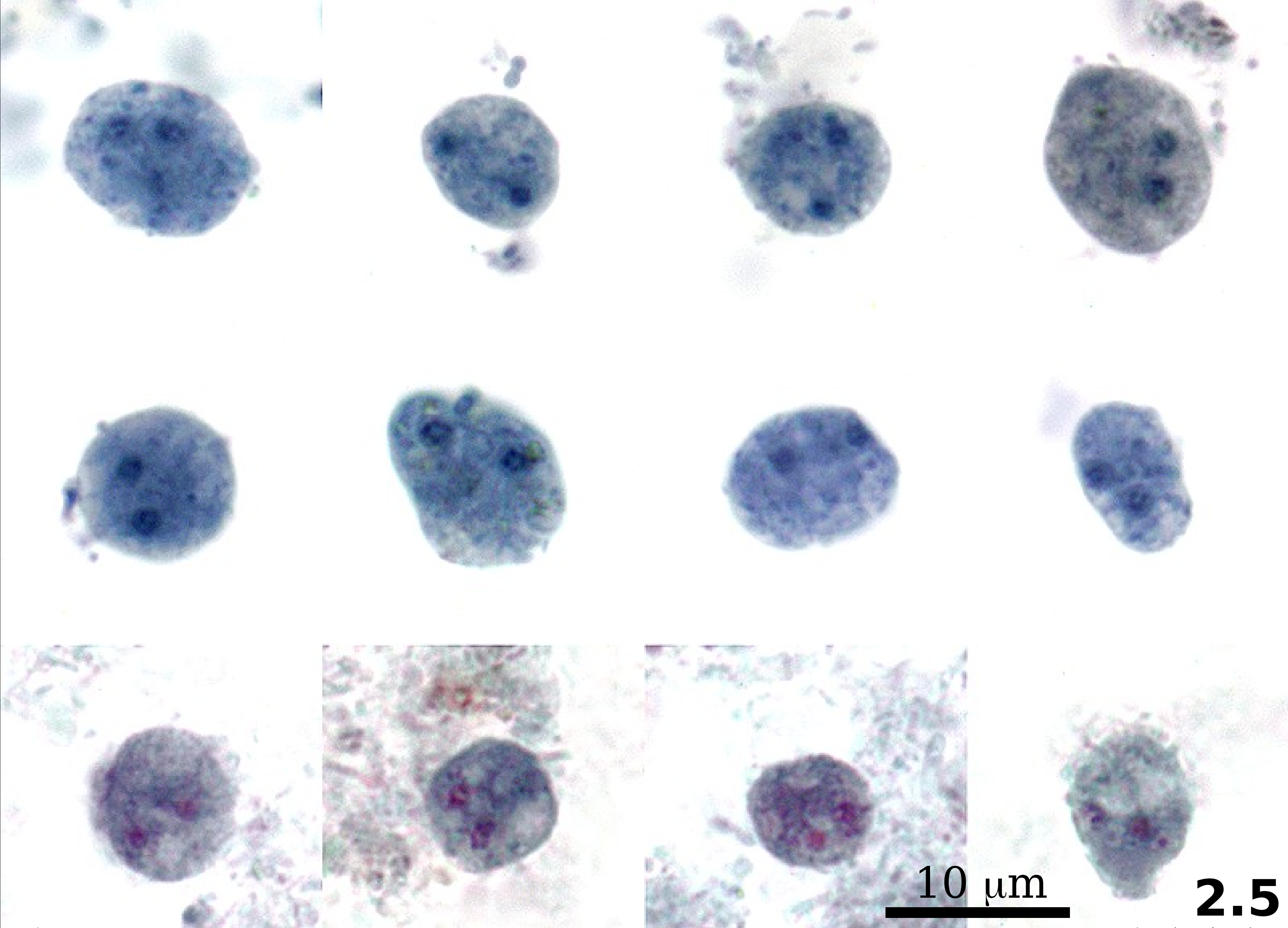



A
10 μm

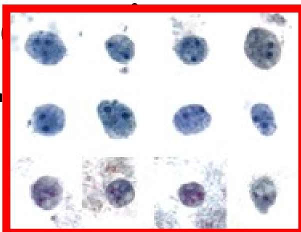
2.4 Cysts of *Giardia lamblia,* stool smear. Note the oval shape, smooth cyst wall, axonemes (A), and four nuclei, usually not all of which are visible in one focal plane. The cytoplasm often is retracted from the cyst wall in fixed specimens, leaving a clear space. The cyst normally would be found in formed stools, and is the infective stage. Although ingestion of cysts from human feces accounts for most cases of giardiasis, there are numerous reservoir hosts, e.g., beavers, and infections have been acquired by persons who drank what appeared to be pristine stream water or melted snow contaminated with cysts of animal origin. Bottom row, trichrome stain.

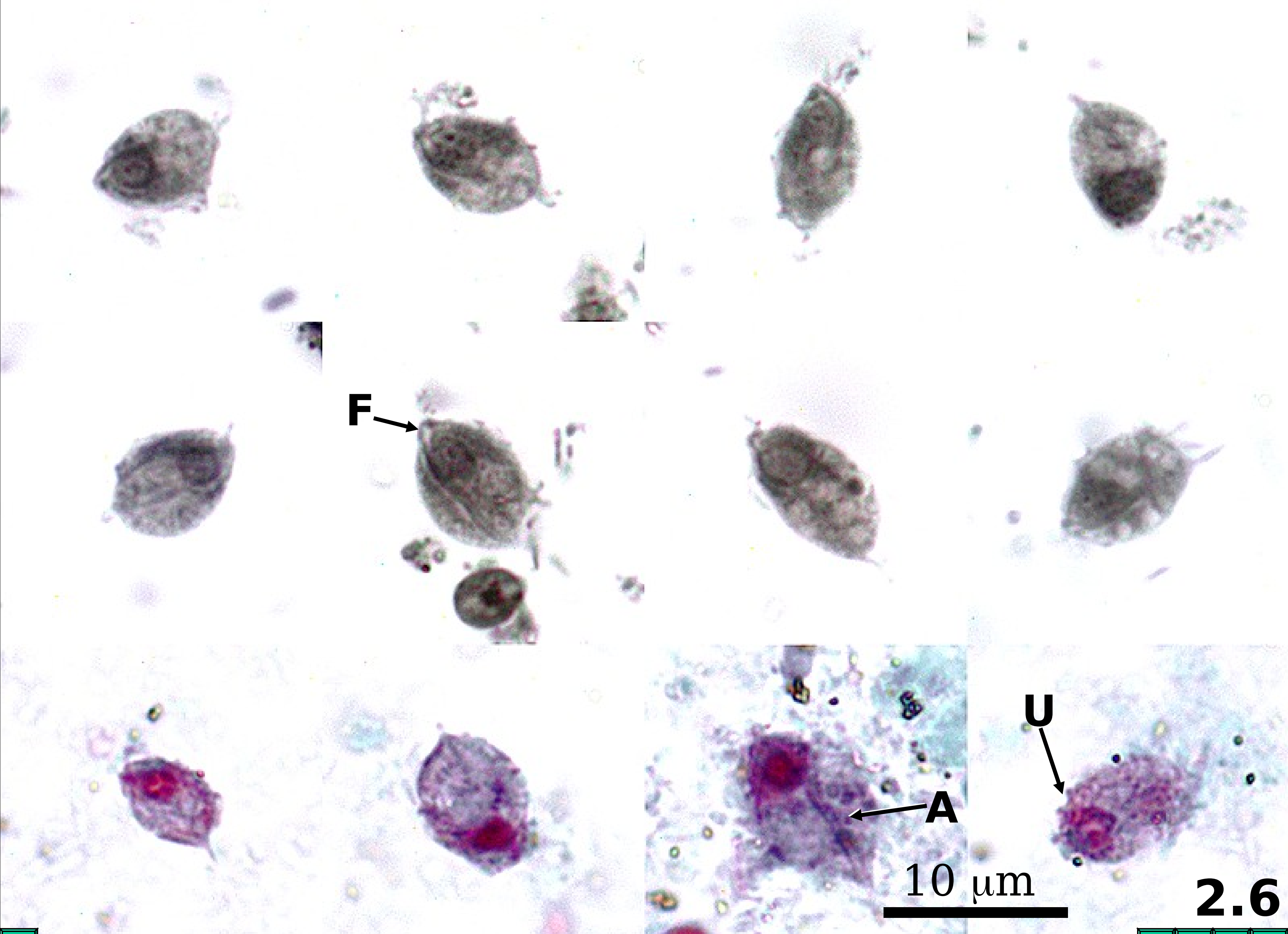
- back to trophozoite of *Giardia lamblia*




10 µm

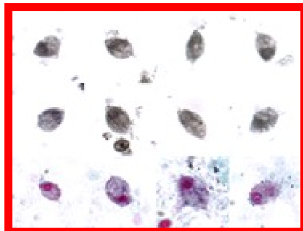
2.5 Trophozoites of *Dientamoeba fragilis,* stool smear. Although the trophozoite is ameboid and there are no flagellated stages in the life cycle, this parasite is actually a trichomonad flagellate. Approximately 60% of specimens possess two nuclei (which are still connected by a mitotic spindle). The cytoplasm usually contains endocytosed material, and while not very obvious in these photographs, the nuclear chromatin typically occurs in 3-5 clumps. In contrast to most intestinal protozoa, there is no cyst, and the trophozoite is the infective stage. Infections apparently are acquired by ingesting eggs of the pinworm, *Enterobius vermicularis,* that are hyperparasitized by trophozoites of *D. fragilis.* Although it is usually considered harmless, th some evidence that *D. fragilis* can cause diarr Bottom row, trichrome stain.

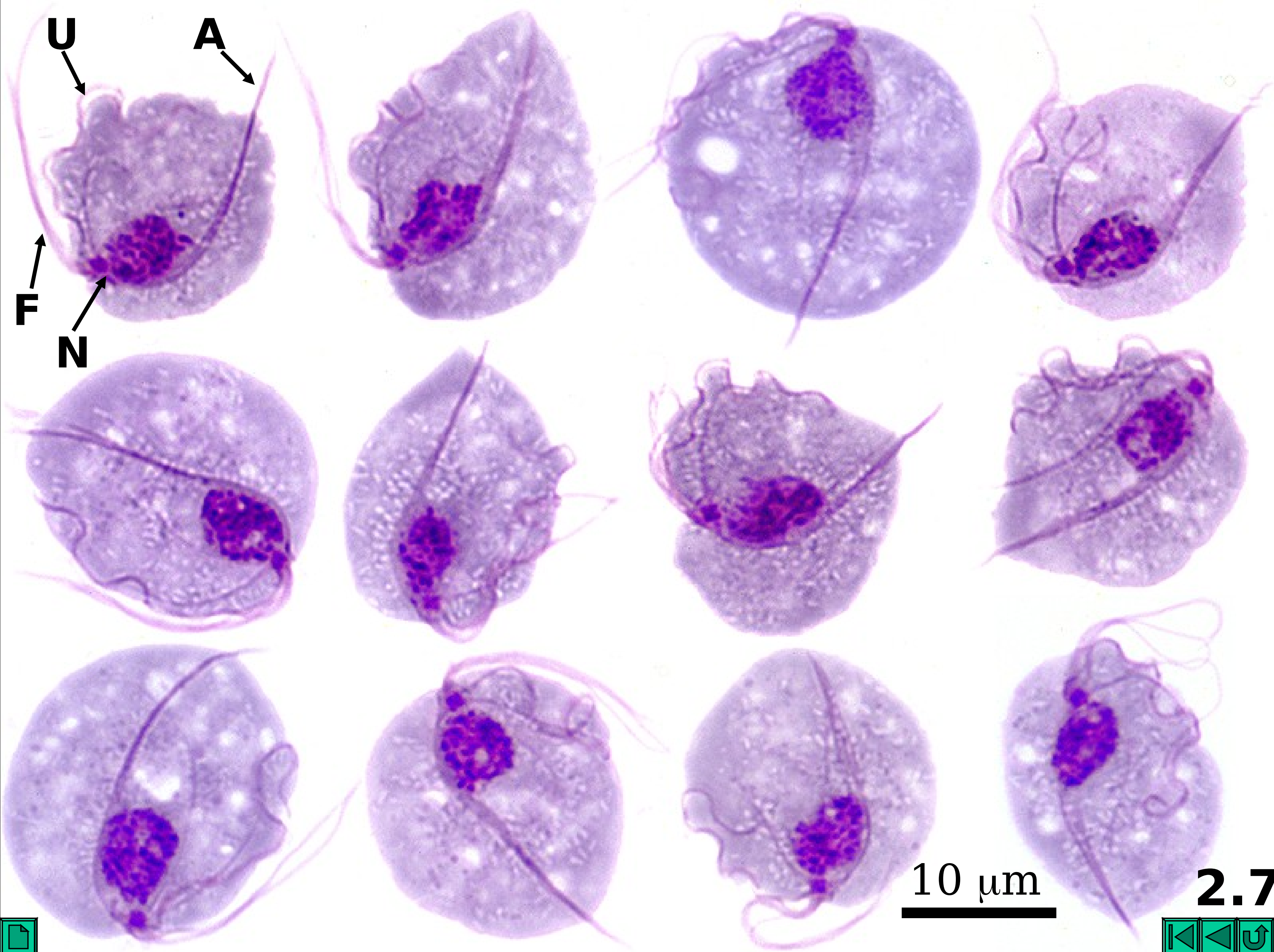




2.6

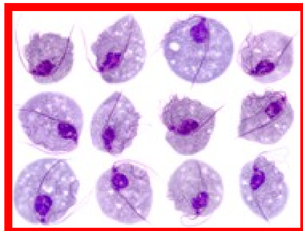
2.6 Trophozoites of *Pentatrichomonas hominis,* stool smear. Although details are difficult to see in these specimens, this organism possesses a single nucleus, undulating membrane (U), five anterior flagella (F), and axostyle (A). Transmission is direct, via fecal-oral contamination. There is no cyst stage, and the trophozoite survives passage through the stomach, unlike the trophozoites of most protozoa. This organism is harmless, although its presence indicates unsanitary conditions. First two rows, hematoxylin stain; bottom row, trichrome stain.

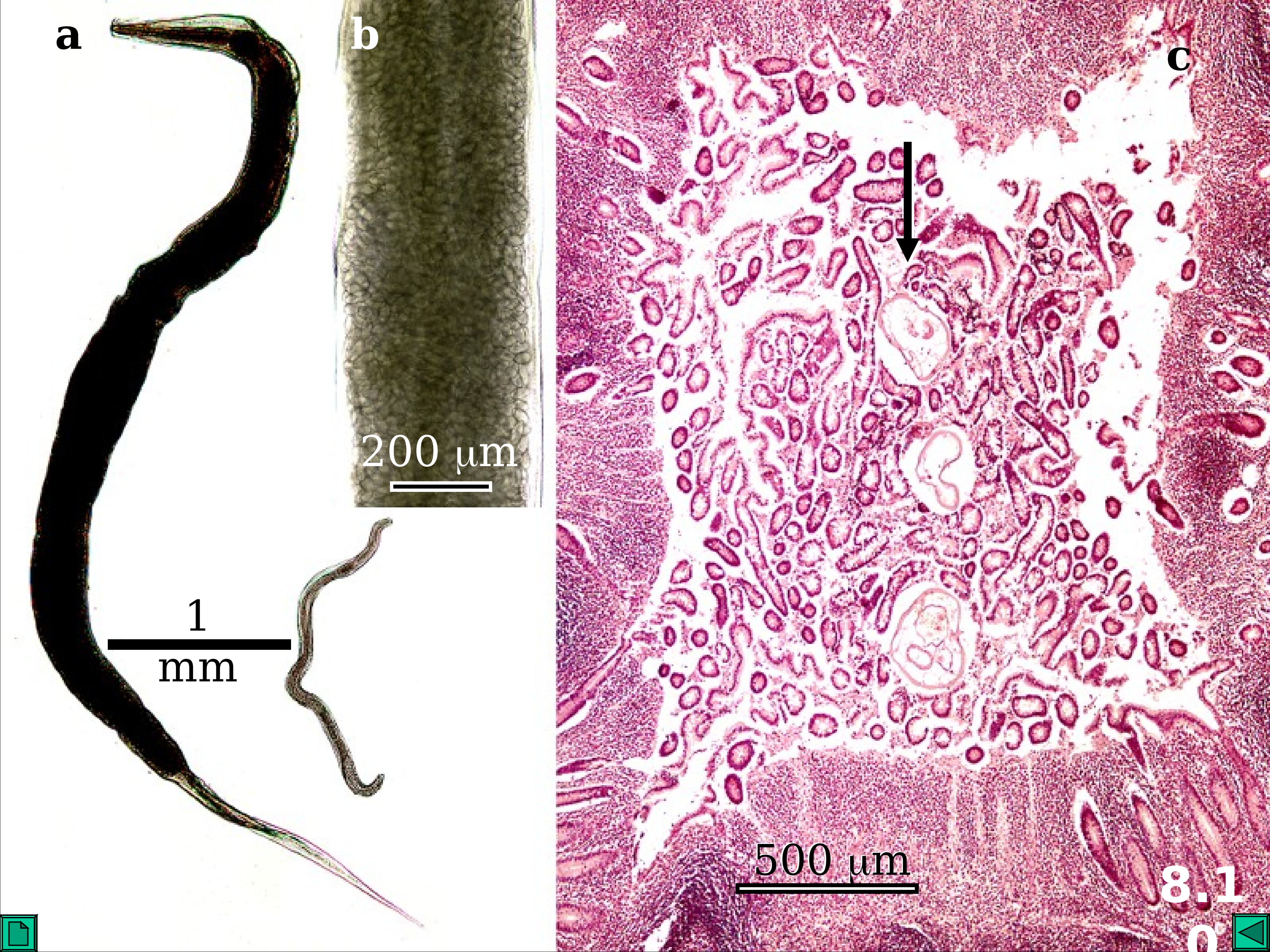




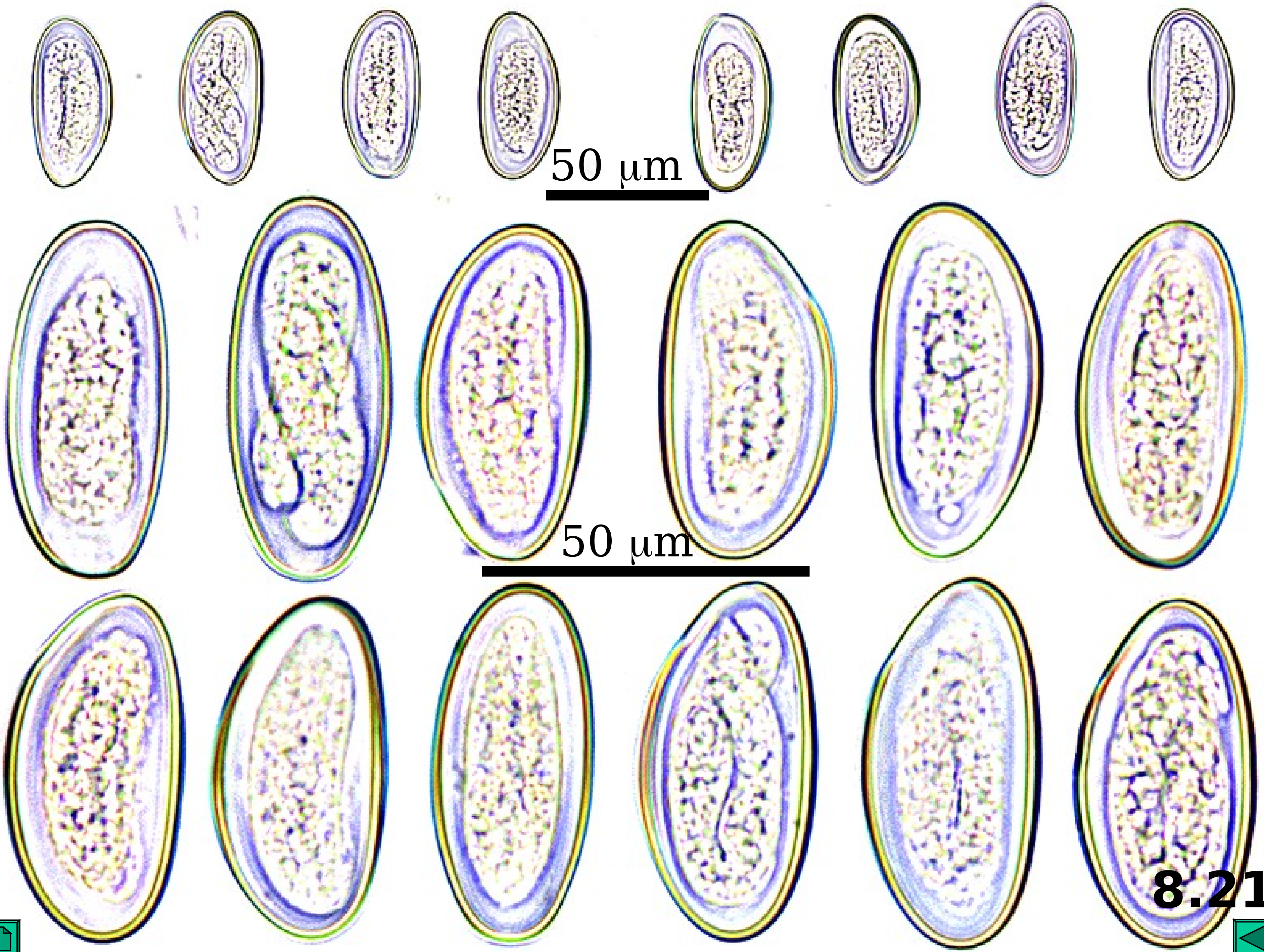
2.7

2.7 Trophozoites of *Trichomonas vaginalis,* culture smear. Note the presence of a single nucleus (N), undulating membrane (U), four anterior flagella (F), and axostyle (A). As for all trichomonads, there is no cyst stage, and transmission is direct, usually via sexual intercourse but also by sharing washcloths. Symptoms range from none to a painful discharge in females and prostatitis in males.



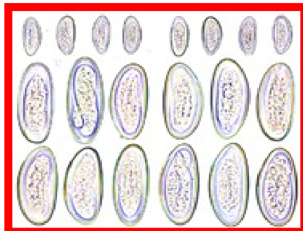

a
b
200 µm
1 mm
c
500 µm

8.10 *Enterobius vermicularis*. **a.** Adult male (on right) and female. Note long pointed tail of female, hence the name “pinworm.” **b.** Higher magnification of the female, showing the gravid uterus filling the pseudocoelom. **c.** Histological section of appendix, showing three cross sections of pinworms in the lumen (arrow). Although often residing in the appendix, the worms are not believed to cause appendicitis. Infection occurs when the eggs containing L_3s are inhaled or swallowed. The major symptom of infection is perianal itching, although more serious problems can result if tissue invasion occurs, and adults sometimes wander into the female reproductive tract.

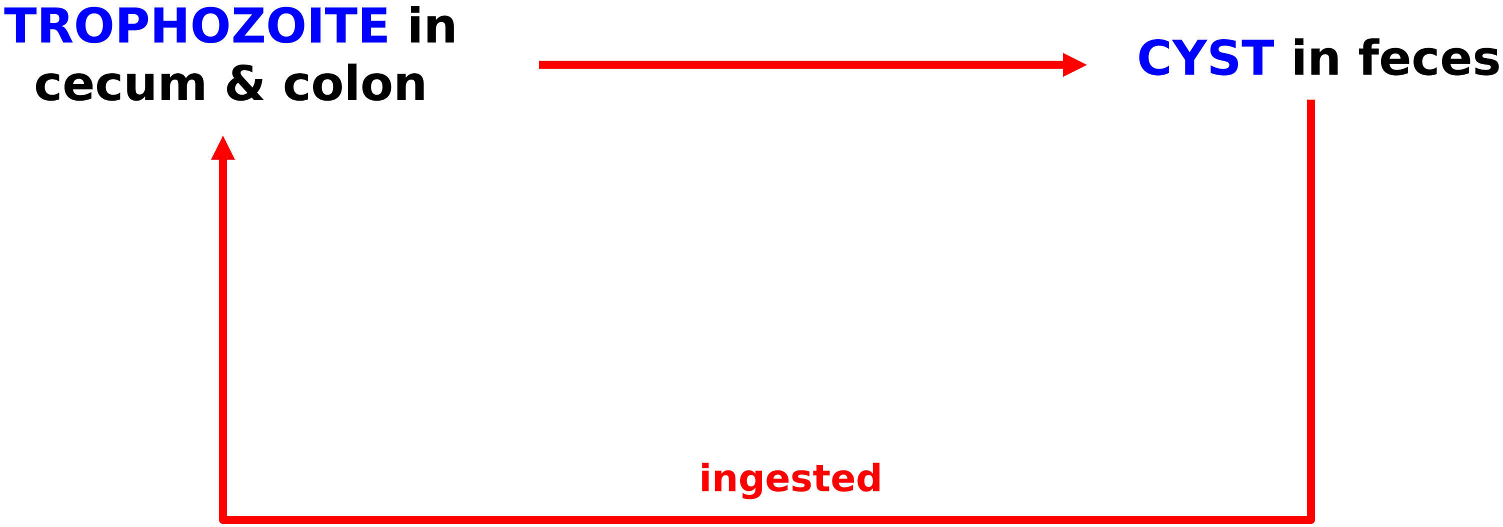


8.21

8.21 Eggs of *Enterobius vermicularis*. Top row is at same magnification as trematode eggs in Chapter 6. These eggs are deposited on the perianal skin by the female at night, and embryonate to the infective L_3 stage within 6 hours. Eggs soon contaminate bed sheets, clothing, and, because they are easily lifted aloft in air currents, the surrounding room. When viewed on edge, the eggs appear flat on one side.



Life cycle of *Chilomastix mesnili*

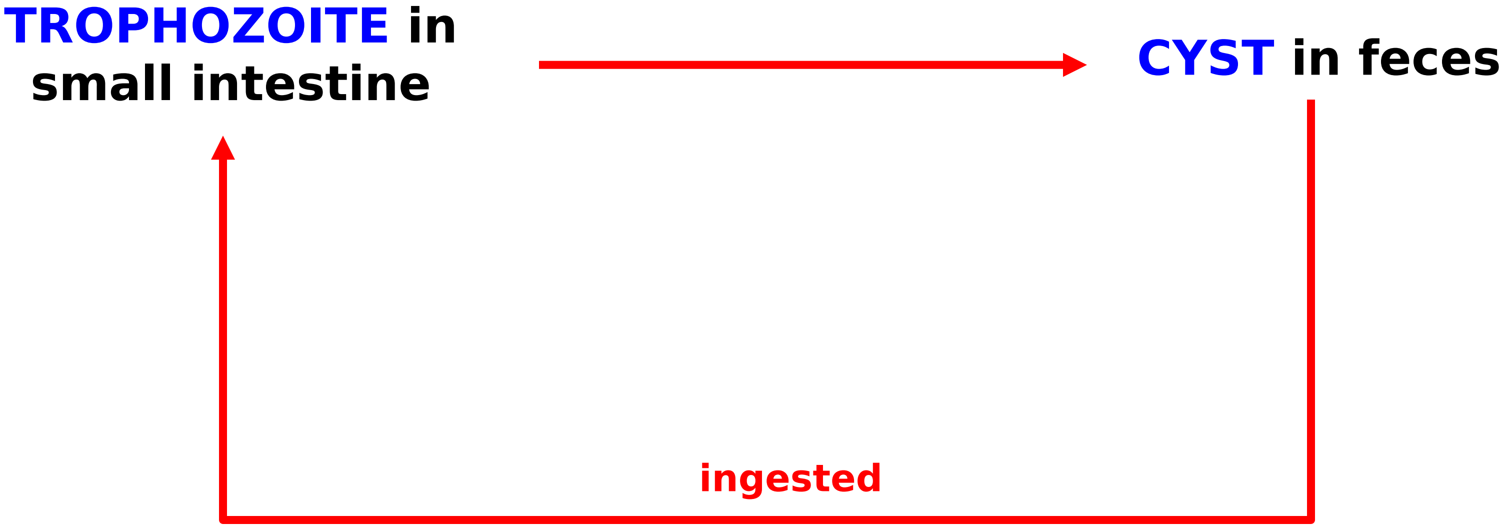


TROPHOZOITE in
cecum & colon

CYST in feces

ingested

Life cycle of *Giardia lamblia*

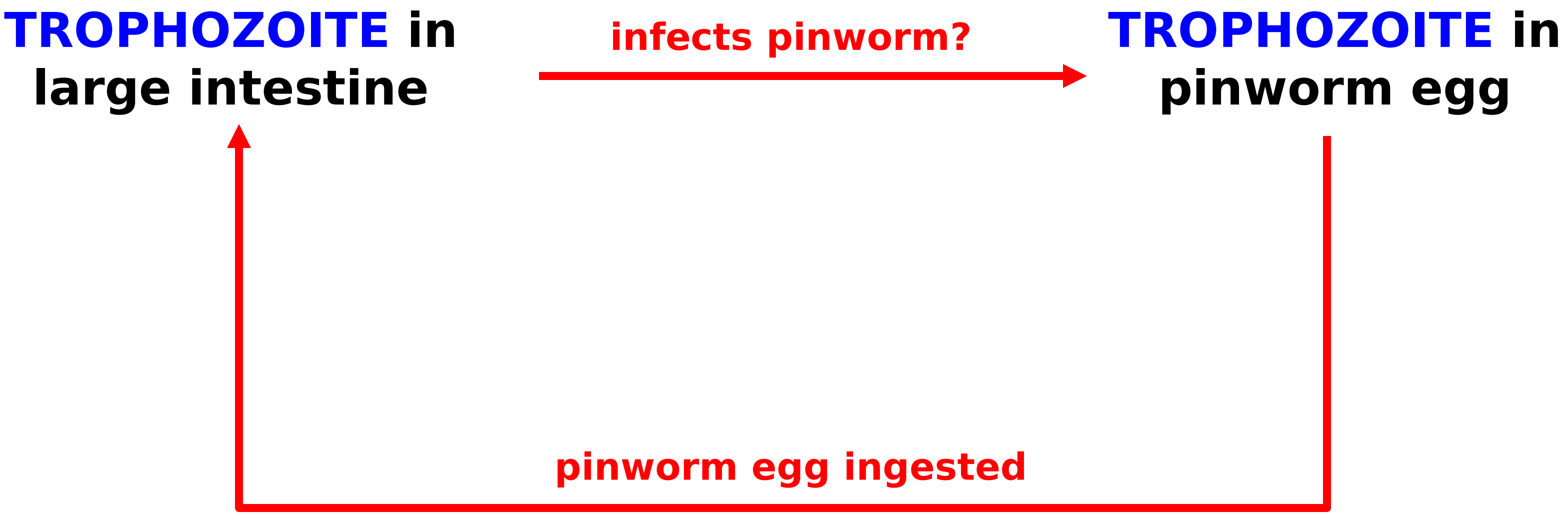


TROPHOZOITE in small intestine

CYST in feces

ingested

Life cycle of *Dientamoeba fragilis*



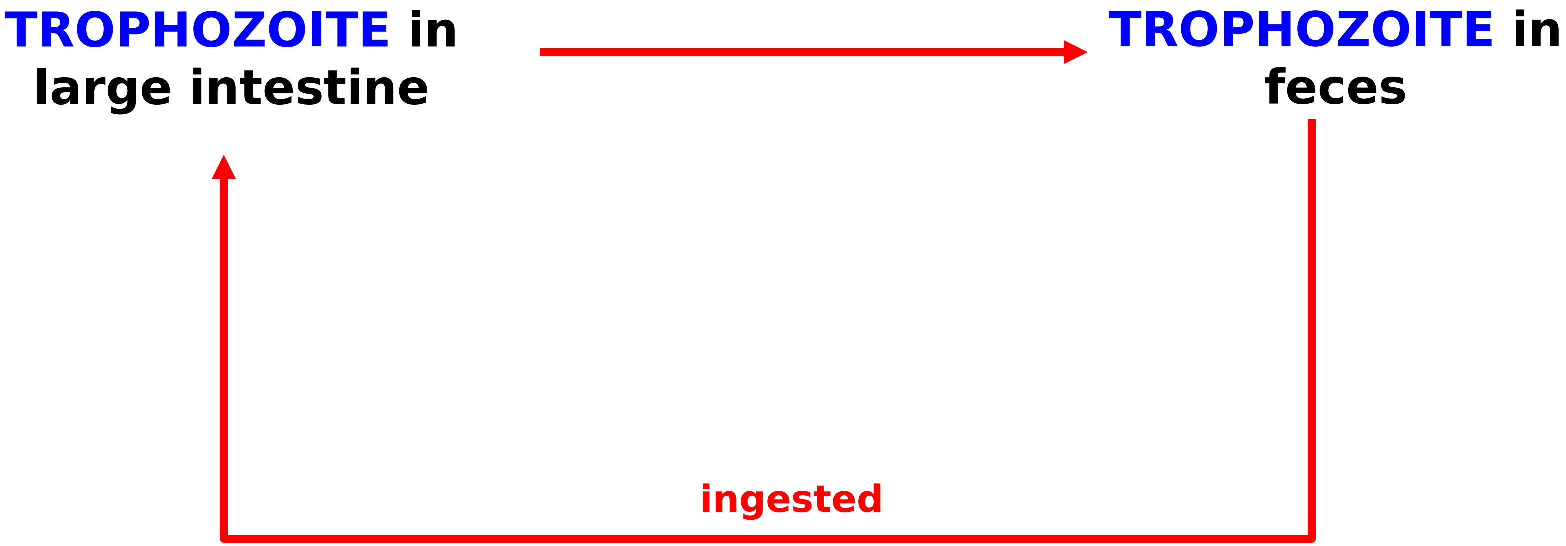
TROPHOZOITE in
large intestine

infects pinworm?

TROPHOZOITE in
pinworm egg

pinworm egg ingested

Life cycle of *Pentatrichomonas hominis*

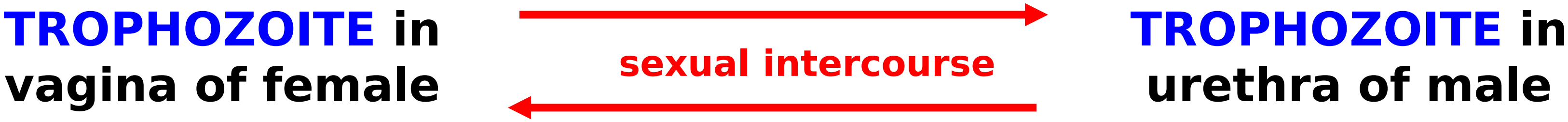


TROPHOZOITE in large intestine

TROPHOZOITE in feces

ingested

Life cycle of *Trichomonas vaginalis*



TROPHOZOITE in
vagina of female

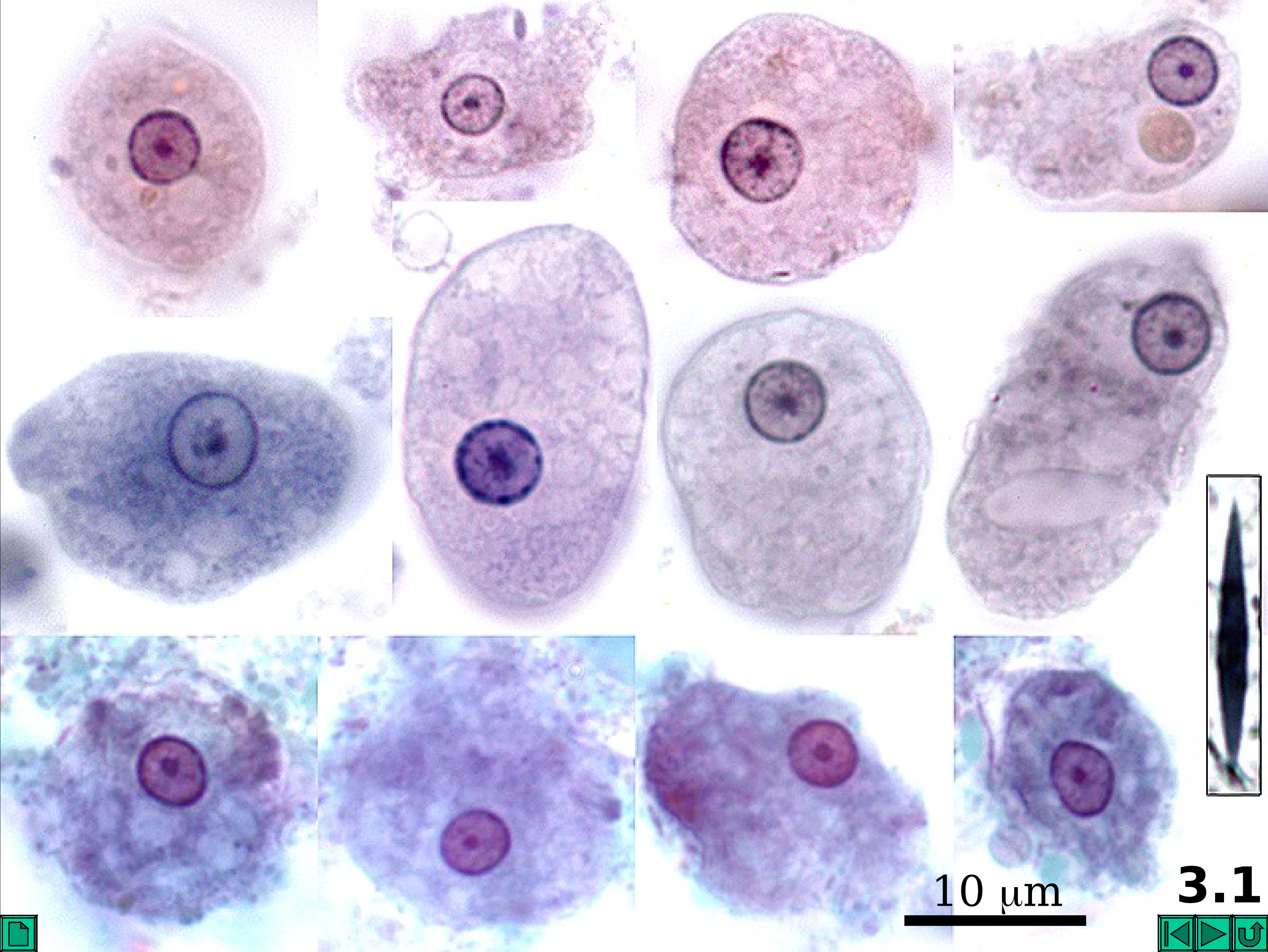
sexual intercourse

TROPHOZOITE in
urethra of male

3. Amoebae & Ciliates

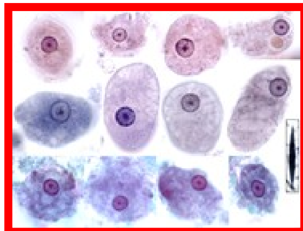
- Trophozoites of *Entamoeba histolytica*
- Cysts of *Entamoeba histolytica*
- Trophozoites of *Entamoeba coli*
- Cysts of *Entamoeba coli*
- Trophozoites of *Endolimax nana*
- Cysts of *Endolimax nana*
- Trophozoites of *Iodamoeba butschlii*
- Cysts of *Iodamoeba butschlii*
- Cysts of *Blastocystis hominis*
- Trophozoites of *Acanthamoeba culbertsoni*
- *Naegleria fowleri* in brain
- Trophozoites of *Balantidium coli*
- Cysts of *Balantidium coli*
- Intestinal balantidiasis and amebiasis

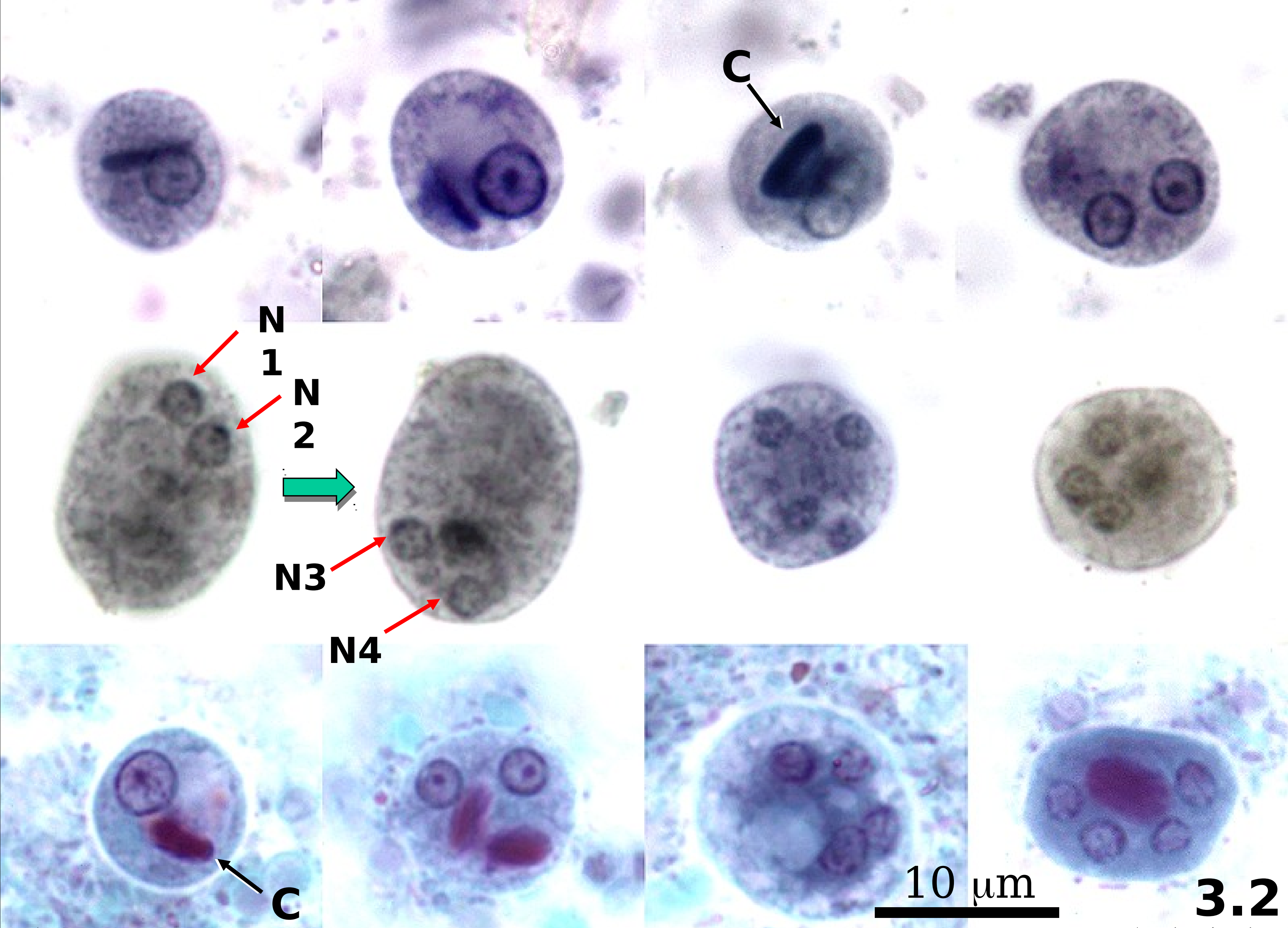
I T



3.1

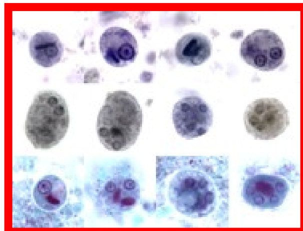
3.1 Trophozoites of *Entamoeba histolytica,* stool smear. A nucleus with a central endosome and a fine peripheral ring of chromatin distinguishes this parasite from *E. coli*. Trophozoites would be found mainly in loose stools. Infection occurs when the cyst is ingested in fecally contaminated food or water. This parasite is capable of causing ulcerative colitis, resulting in severe dysentery, as well as extraintestinal amebiasis, including fatal brain infections. Charcot-Leyden crystals, representing the crystallized contents of granules from eosinophil leukocytes (insert), may also be found in a fecal smear. Bottom row, trichrome stain.

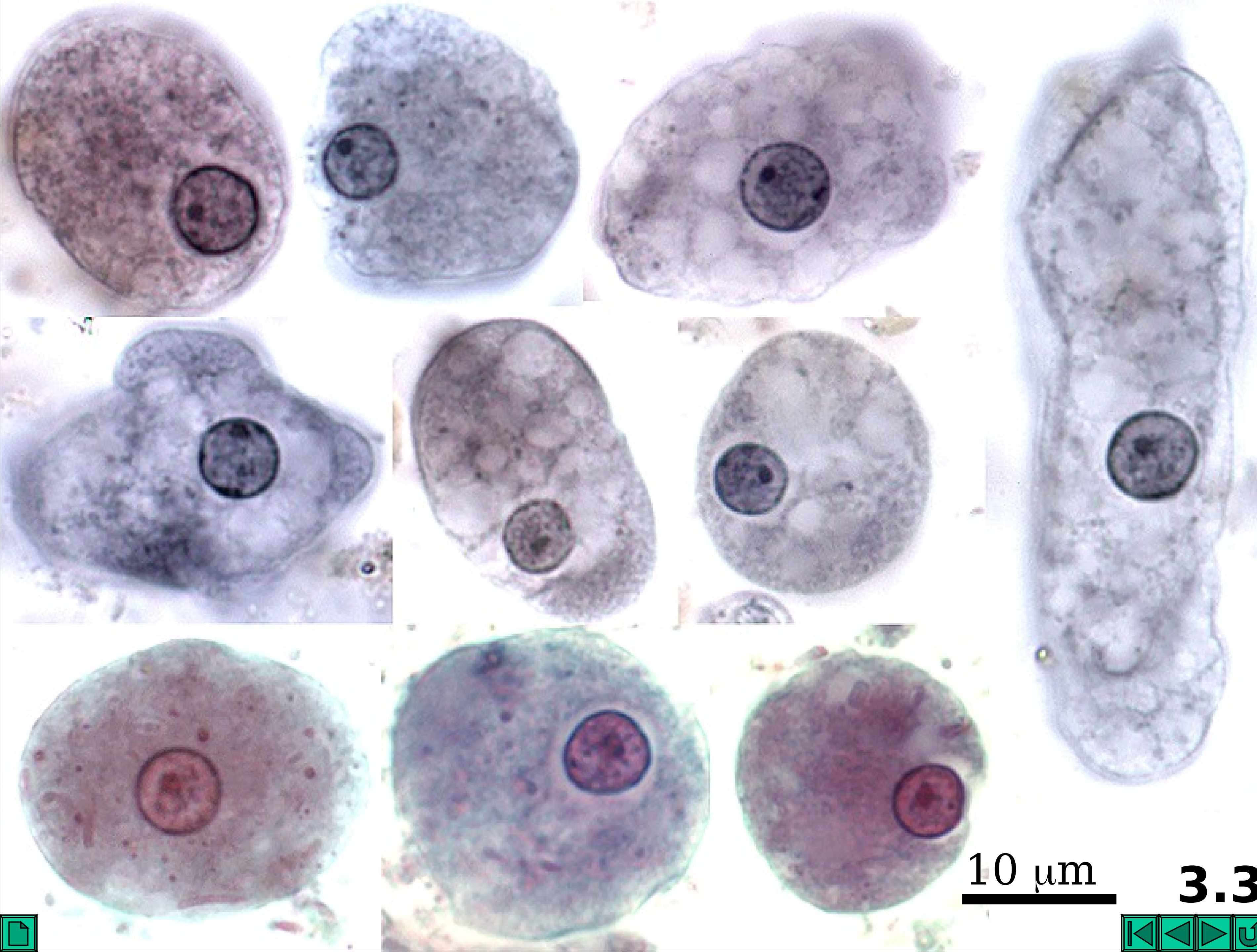



C
N1
N2
N3
N4
C
10 µm

3.2 Cysts of *Entamoeba histolytica,* stool smear. Note the presence of four or fewer nuclei. Although all four nuclei may not be visible in the same plane, they can be counted by carefully adjusting the fine focus control (N1-N4, second row). Chromatoidal bars (C), when present in immature cysts, usually have blunt ends, versus splintered ends in cysts of *E. coli*. Cysts would be found mainly in formed stools, and are the infective stage. Bottom row, trichrome stain.

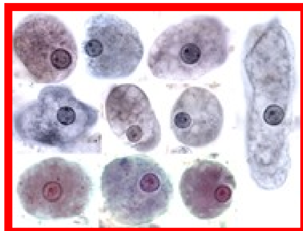
- Back to trophozoite of *Entamoeba histolytica*

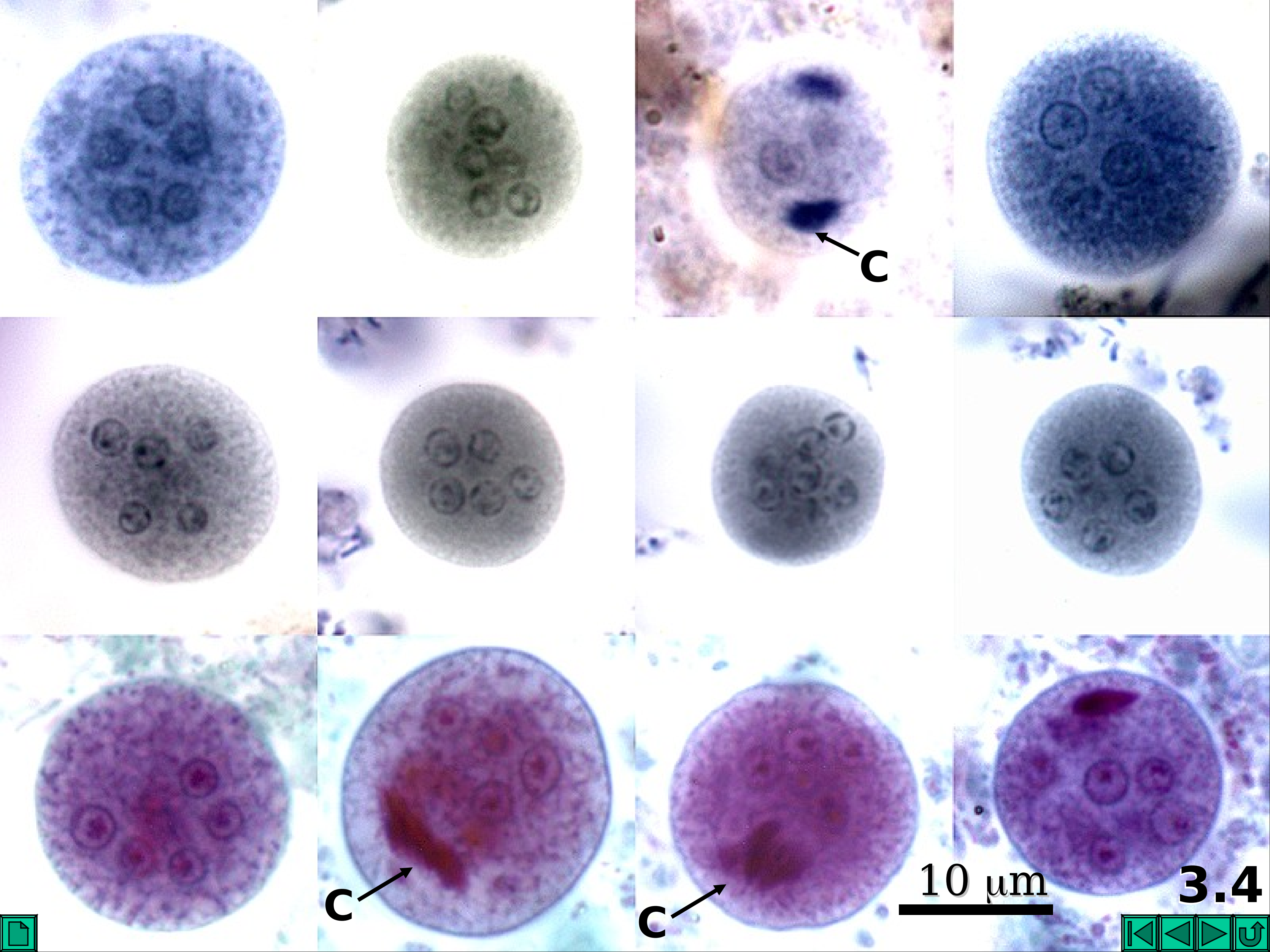




3.3

3.3 Trophozoites of *Entamoeba coli,* stool smear. This species can be distinguished from *E. histolytica* by the usually eccentric location of the nuclear endosome and the relatively coarser, larger granules in the ring of peripheral chromatin. Also, the cytoplasm tends to be “dirtier” than that of *E. histolytica,* with more phagocytosed bacteria. Although harmless, accurate identification of this parasite is important, because it is an indicator of fecal-oral contamination, and because it could be confused with the pathogenic species. Infection occurs when the cyst is ingested. Trophozoites would be found mainly in loose stools. Bottom row, trichrome stain.

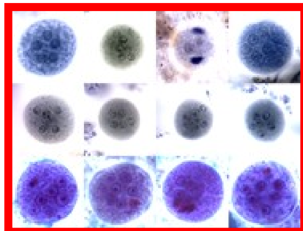


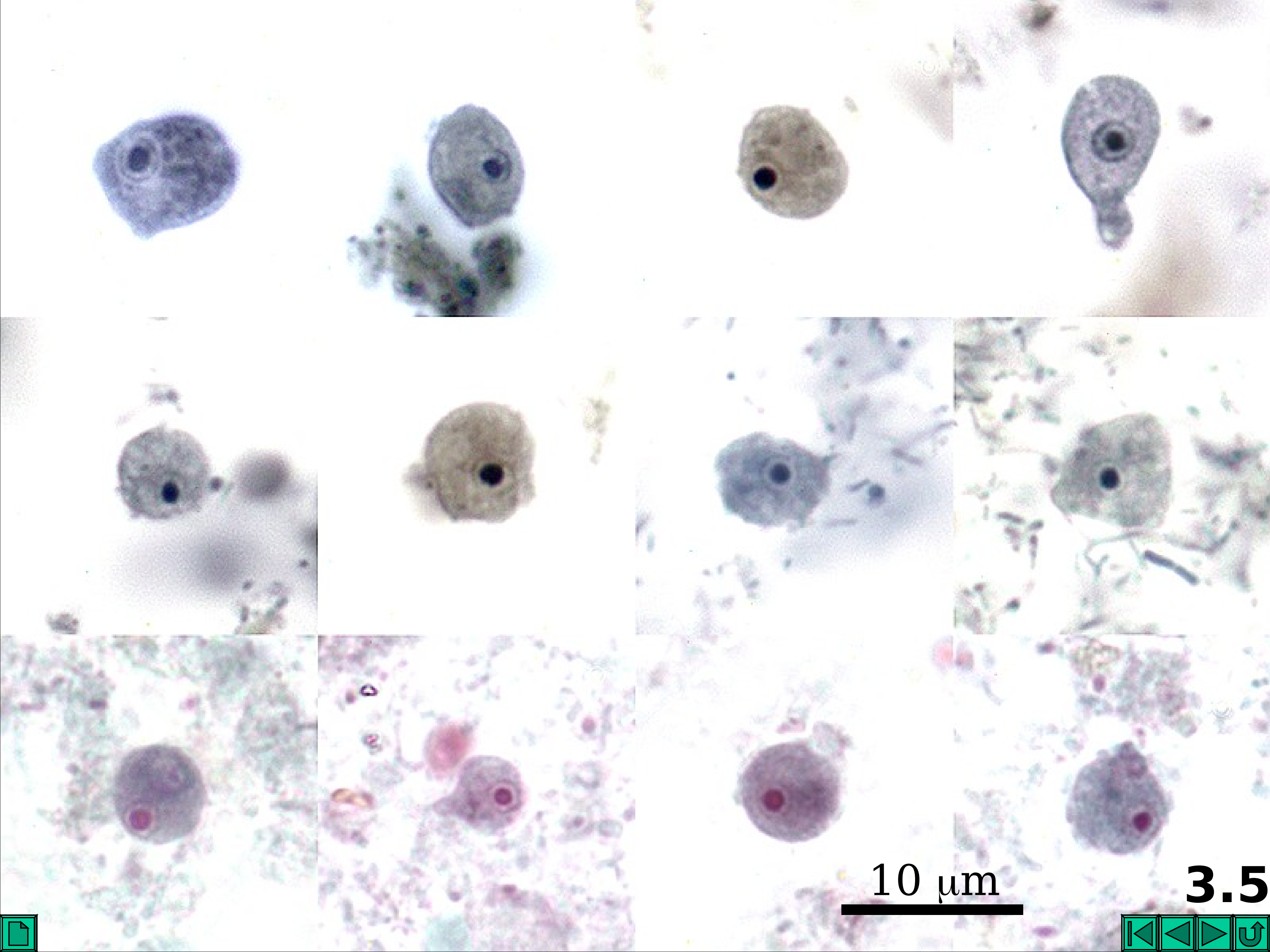


3.4

3.4 Cysts of *Entamoeba coli,* stool smear. Note the presence of more than four nuclei (actually, eight are present in mature cysts). Chromatoidal bars (C) in immature cysts have splintered ends, versus blunt ends in cysts of *E. histolytica*. Cysts would be found mainly in formed stools, and are the infective stage. Bottom row, trichrome stain.

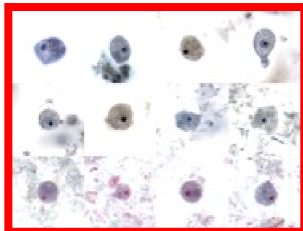
- Back to trophozoite of *Entamoeba coli*

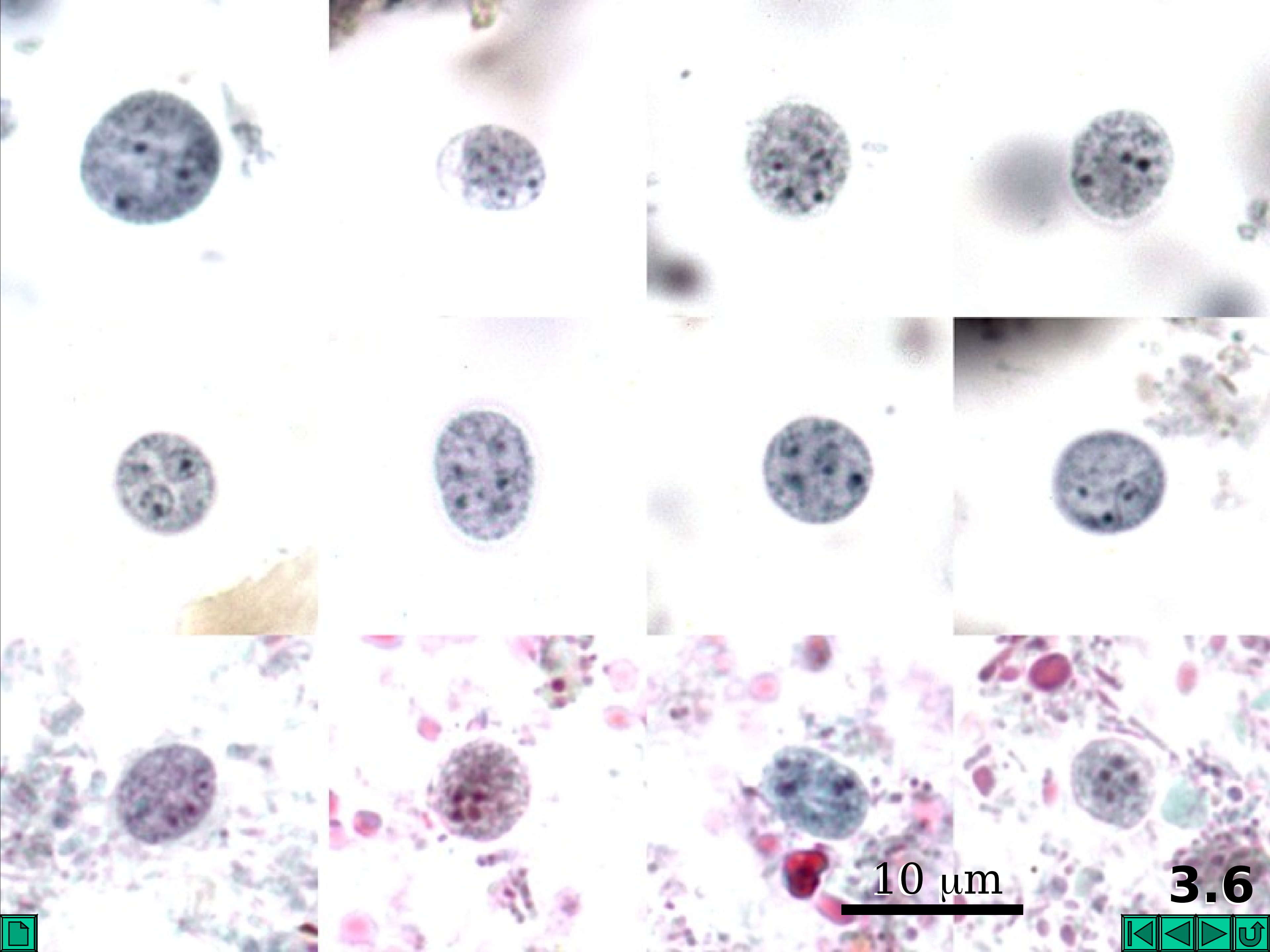




3.5

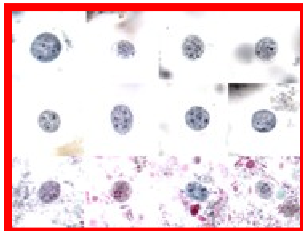
3.5 Trophozoites of *Endolimax nana,* stool smear. Note the small size and prominent nuclear endosome. Although harmless, it is important to be able to identify this parasite, because it is an indicator of fecal-oral contamination, and because it could be confused with the pathogenic species. Infection occurs when the cyst is ingested. Trophozoites would be found mainly in loose stools. Bottom row, trichrome stain.

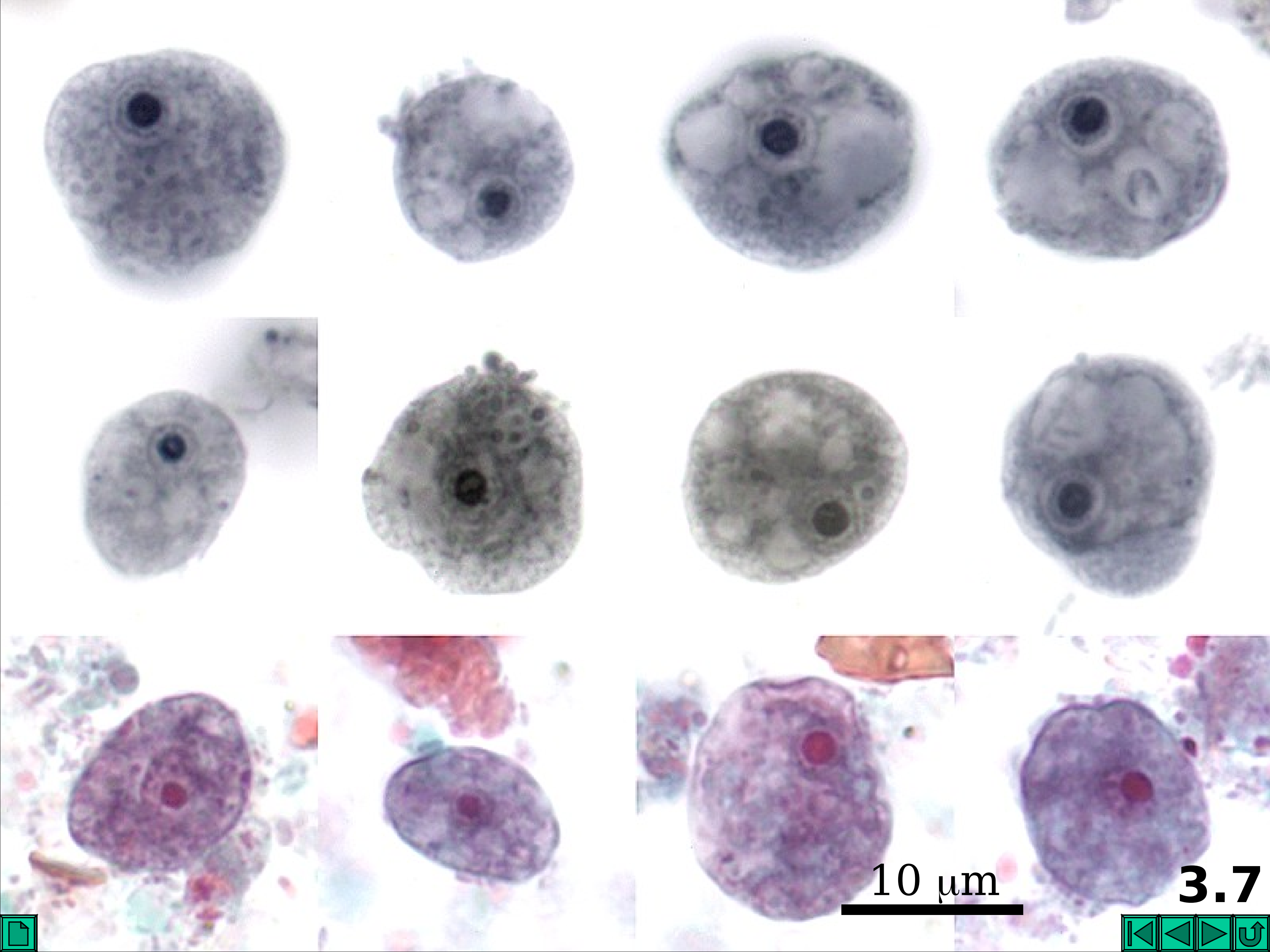



10 µm

3.6 Cysts of *Endolimax nana,* stool smear. Note the small size and presence of up to 4 nuclei with prominent endosomes. Cysts would be found mainly in formed stools, and are the infective stage. Bottom row, trichrome stain.

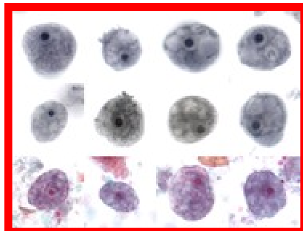
- Back to trophozoite of *Endolimax nana*

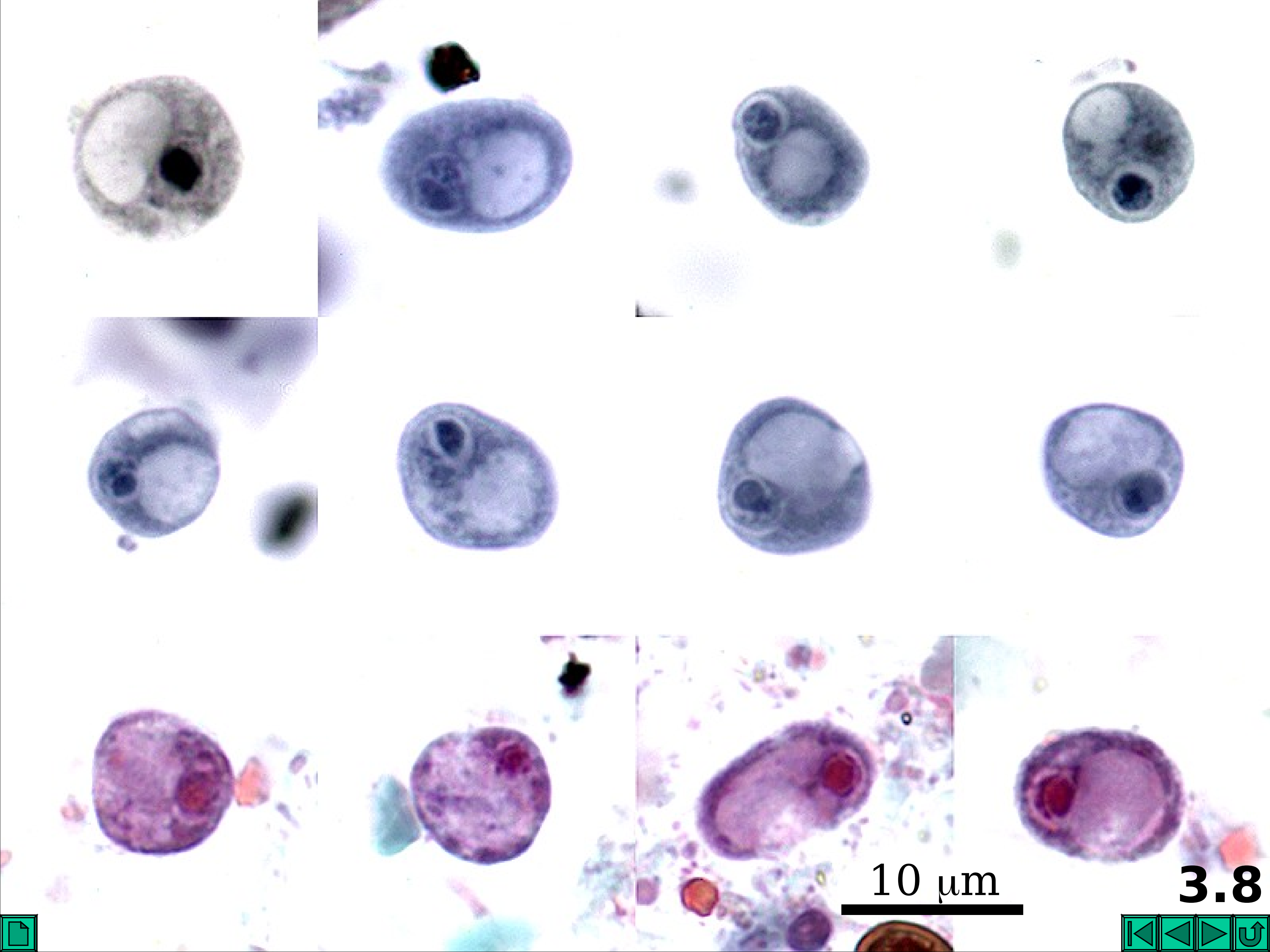




3.7

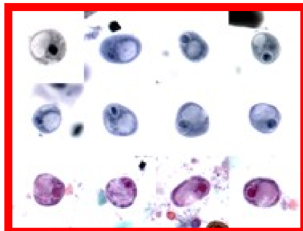
3.7 Trophozoites of *Iodamoeba butschlii,* stool smear. Note the prominent nuclear endosome and numerous cytoplasmic vacuoles. Although usually considered to be harmless, it is suspected of causing diarrhea. Also, it is important to be able to identify this parasite, because it is an indicator of fecal-oral contamination, and because it could be confused with the pathogenic species. Trophozoites would be found mainly in loose stools. Infection occurs when the cyst is ingested. Bottom row, trichrome stain.

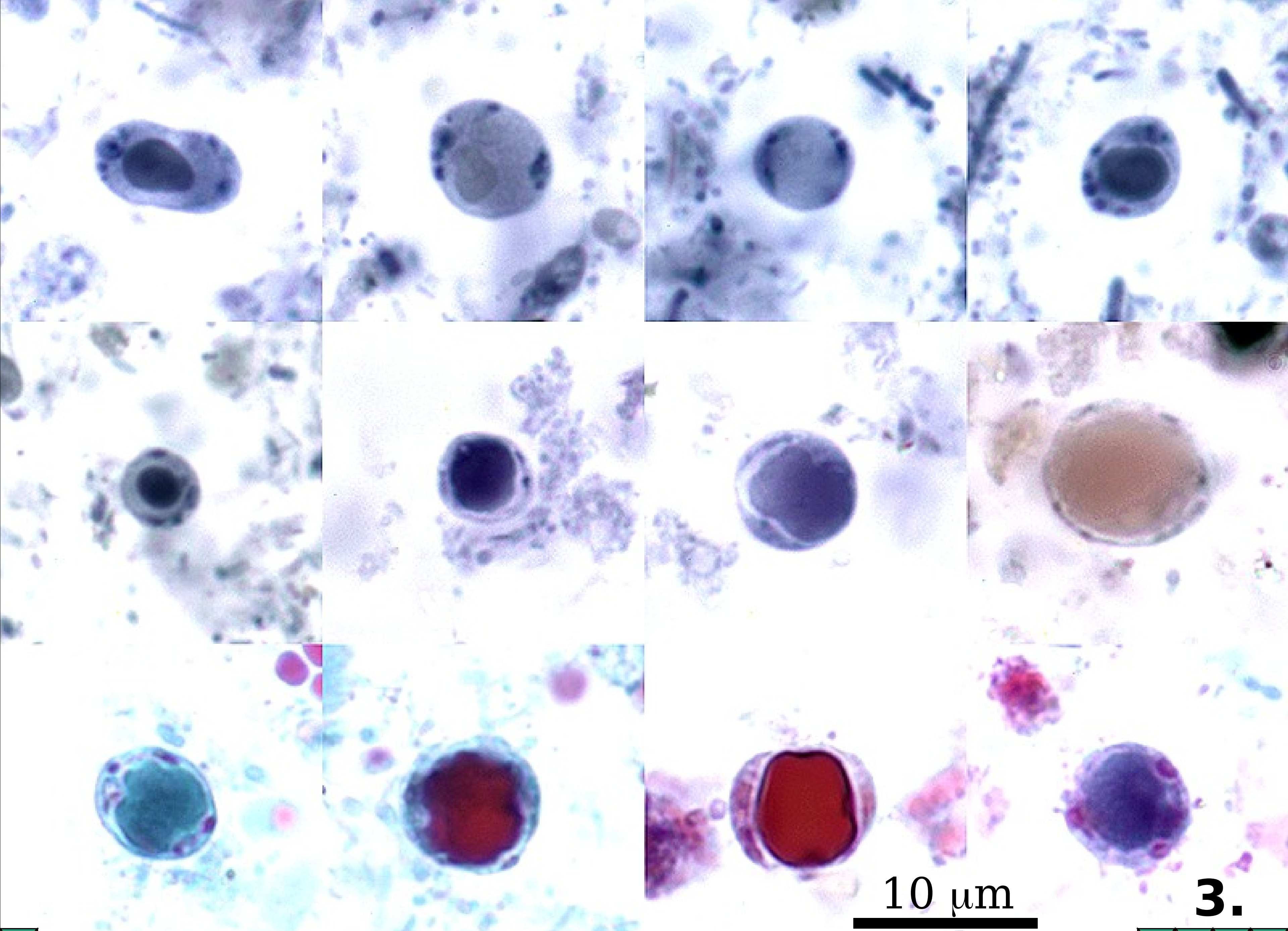



10 µm

3.8 Cysts of *Iodamoeba butschlii,* stool smear. Note the oval shape, single nucleus with prominent endosome, and large, single, glycogen-filled vacuole (called an iodinophilous vacuole, since the glycogen stains with iodine). Cysts would be found mainly in formed stools, and are the infective stage. Bottom row, trichrome stain.

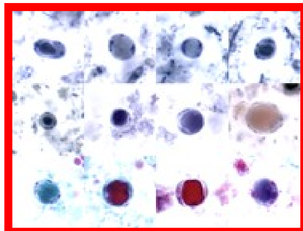
- back to trophozoite of *Iodamoeba butschlii*

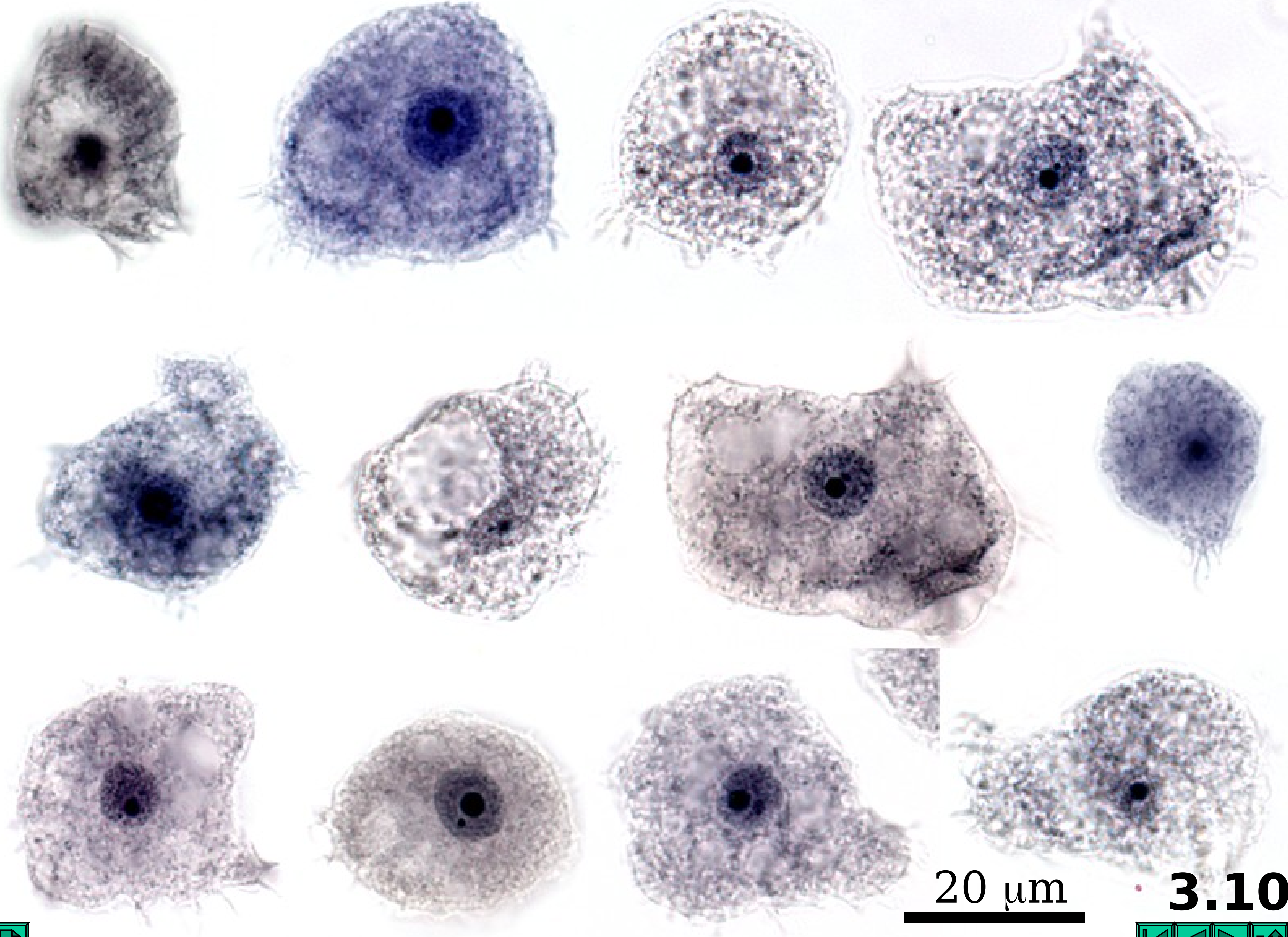




3.

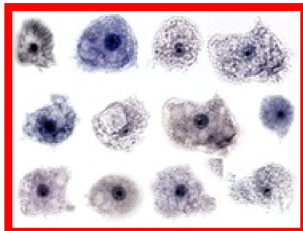
3.9 Cysts of *Blastocystis hominis*. Although considered a yeast by some, others classify it as an amoeba. Cysts may contain a central vacuole-like inclusion surrounded by a thin rim of cytoplasm with a variable number of granules. There is some controversy not only over its taxonomic position, but also whether it can cause diarrhea. Bottom row, trichrome stain.

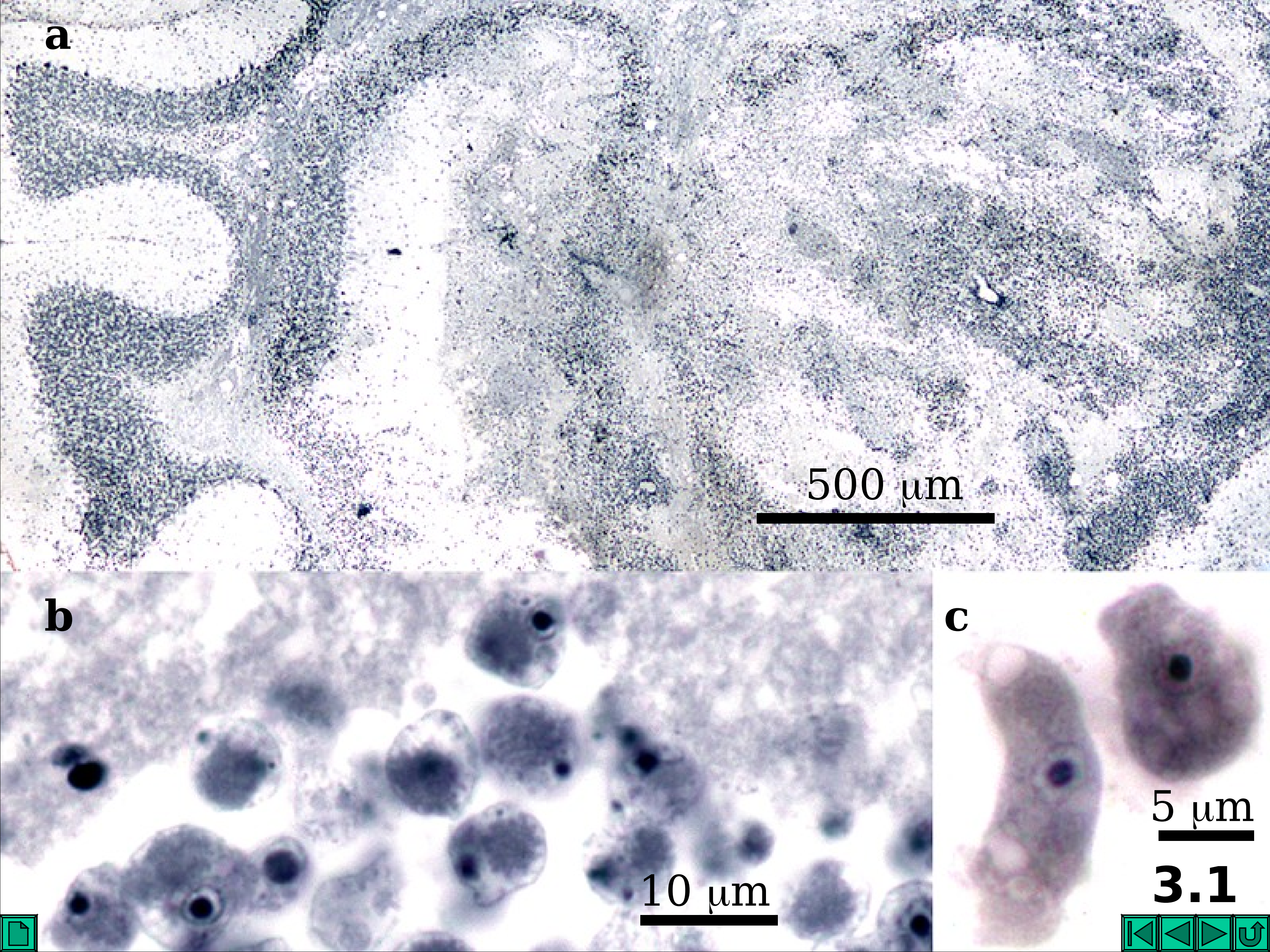




3.10

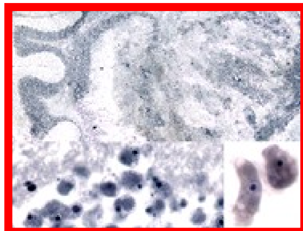
3.10 Trophozoites of *Acanthamoeba culbertsoni*, culture smear. Note the spike-like rhizopods. Certain species of this genus of free-living amoebae have been found as opportunistic parasites of immunocompromised individuals and in immunocompetent persons suffering trauma to the conjunctiva of the eye or using contaminated contact lens cleaning solutions. In immunocompromised individuals, it forms slowly spreading granulomas in the visceral organs, resulting in fatal granulomatous amebic encephalitis (GAE) if reaching the brain. Eye infection may require surgical removal of the eye. The cyst is the infective stage, and it can also be found in biopsies of infected tissues.

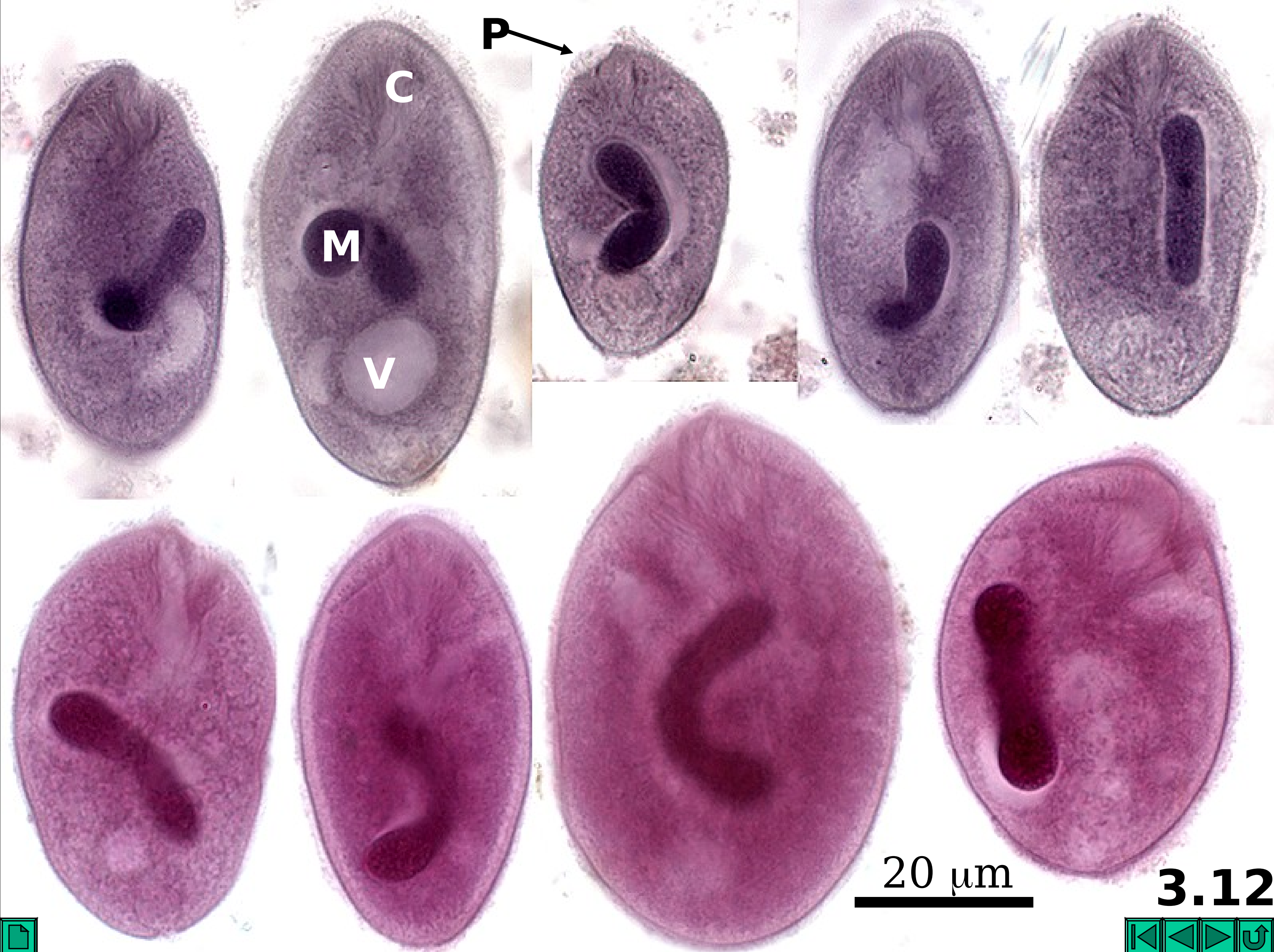



a
500 µm
b
10 µm
c
5 µm

3.1

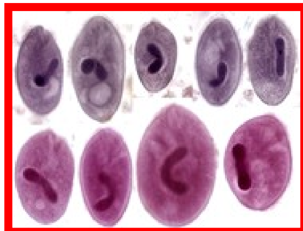
3.11 Histological section of mouse brain infected with *Naegleria fowleri*. **a.** Low magnification view of brain with central necrotic zone. **b.** Individual trophozoites within necrotic zone, each with a prominent endosome. **c.** Trophozoites in a culture smear. Human infections with this opportunistic parasite are contracted by diving into water containing the infective biflagellated form, which adheres to the olfactory epithelium, transforms into the trophozoite, and invades the brain via the olfactory nerve. The resulting primary amoebic meningoencephalitis (PAM) is rapidly fatal. Cysts are not found in the tissues.

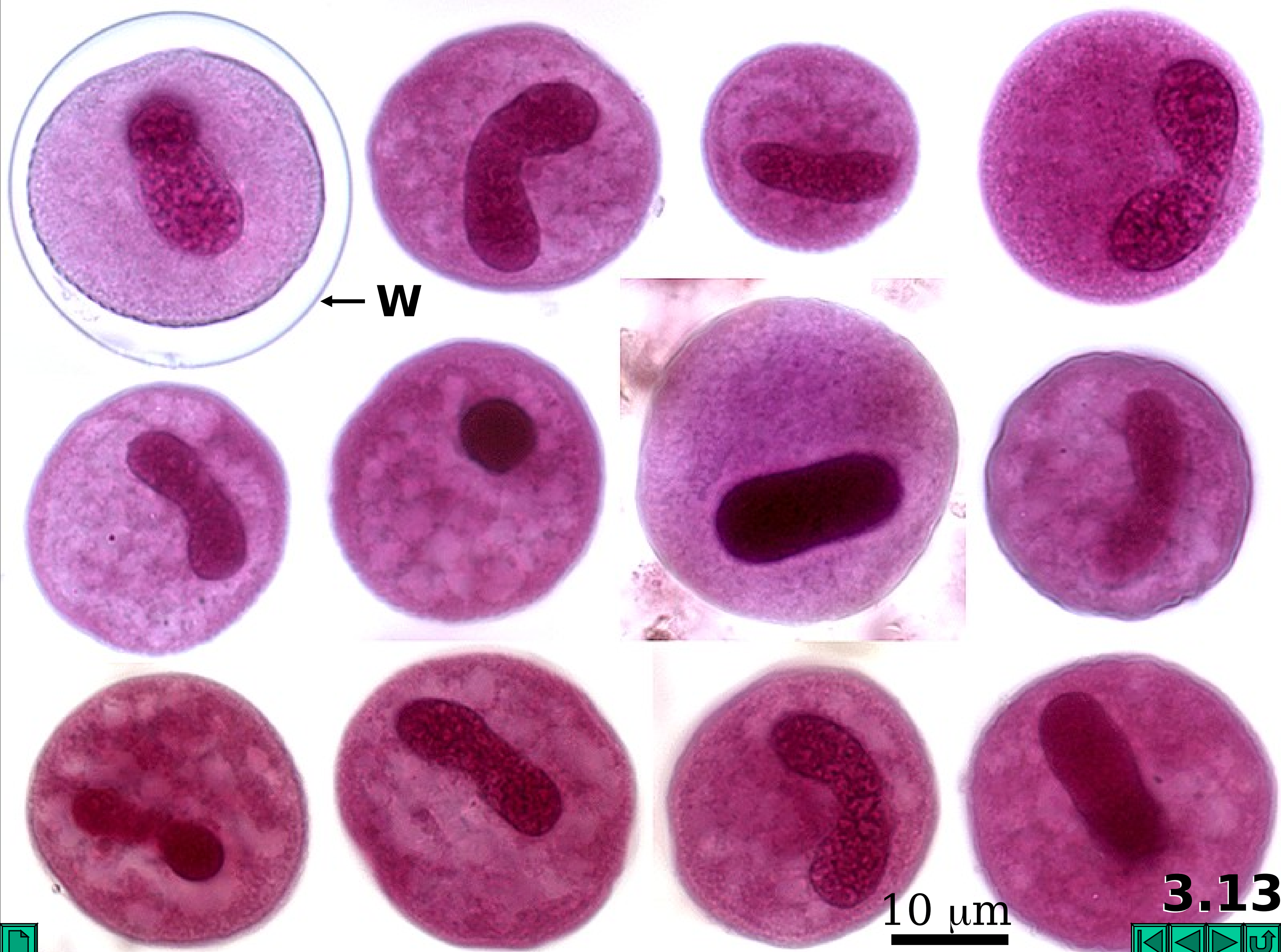




3.12

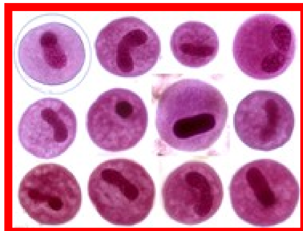
3.12 Trophozoites of *Balantidium coli,* stool smear. Note the oval shape, large curved macronucleus (M), cytostome (C), peristomal cilia (P), and food vacuoles (V). The only pathogenic ciliate parasite of humans, *B. coli* can cause intestinal lesions that result in a disease similar to amoebic dysentery, although this is rare. Trophozoites would be found mainly in loose stools. Infections are established when the infective cyst is ingested with fecally-contaminated food or water. Because this parasite also infects pigs, human infections with *B. coli* are especially common in pig-rearing areas.

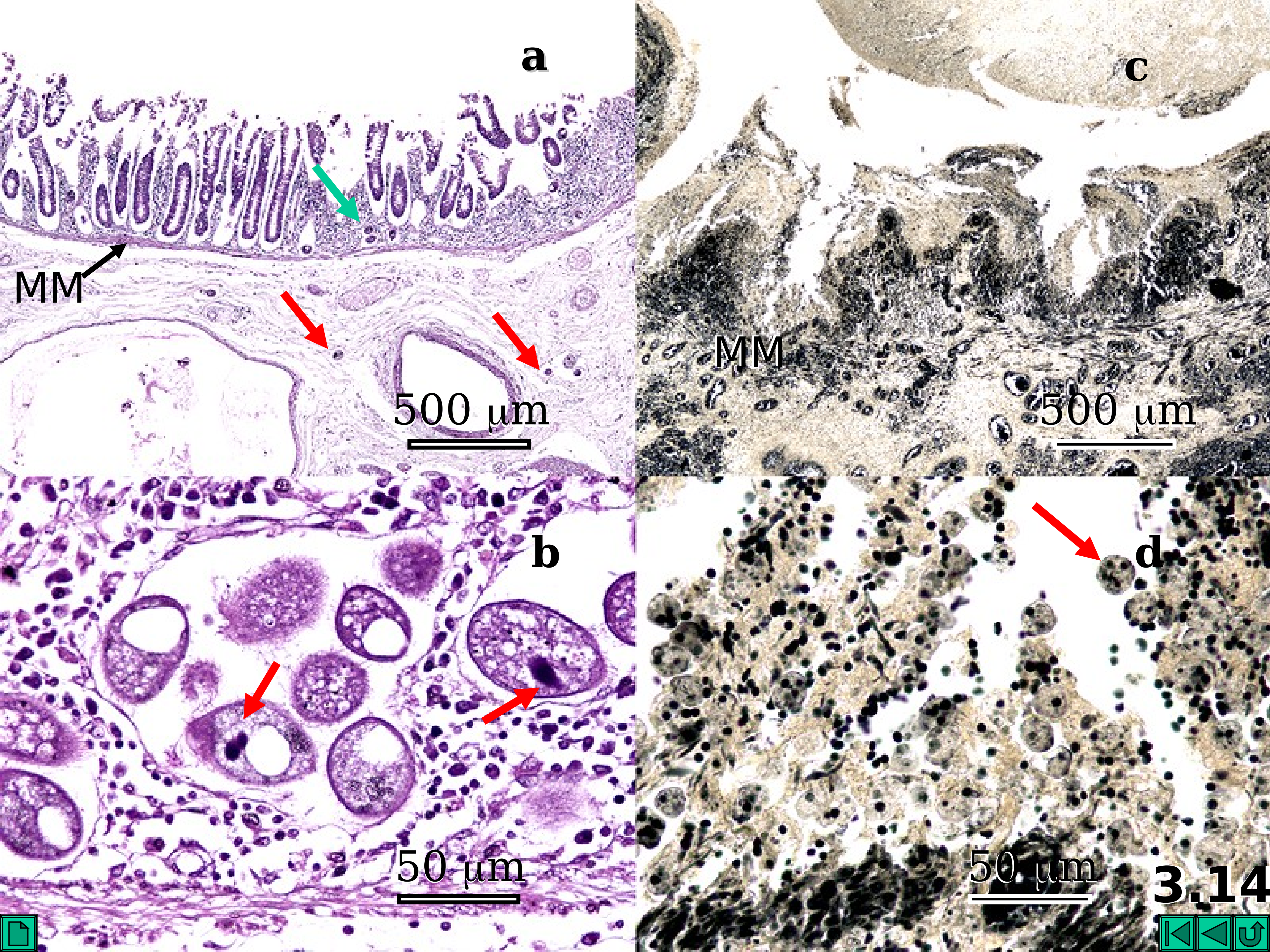



W
10 μm

3.13 Cysts of *Balantidium coli,* stool smear. Note the smooth round shape, large curved macronucleus, and cyst wall (W), which has separated from the cell in one specimen. Cysts would be found mainly in formed stools, and are the infective stage.

- Back to trophozoite of *Balantidium coli*




a
MM
500 µm
b
50 µm
c
MM
500 µm
d
50 µm

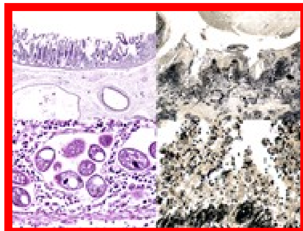
3.14

3.14 Intestinal balantidiasis and amebiasis, histological sections. **a.** Lesion in colon caused by *Balantidium coli*. MM, muscularis mucosae. In addition to trophozoites in the lesion itself (green arrow), there are also trophozoites in lymphatic vessels in the submucosa (red arrows), demonstrating how the infection may spread to other sites. *B. coli* only rarely causes this pathology in humans. **b.** Higher magnification of trophozoites in lesion. Note the macronucleus in some specimens (arrow). **c.** Lesion caused by *Entamoeba histolytica*. MM, muscularis mucosae. **d.** Trophozoites (arrow) at base of the lesion, most of which contain darkly stained, phagocytosed red blood cells.

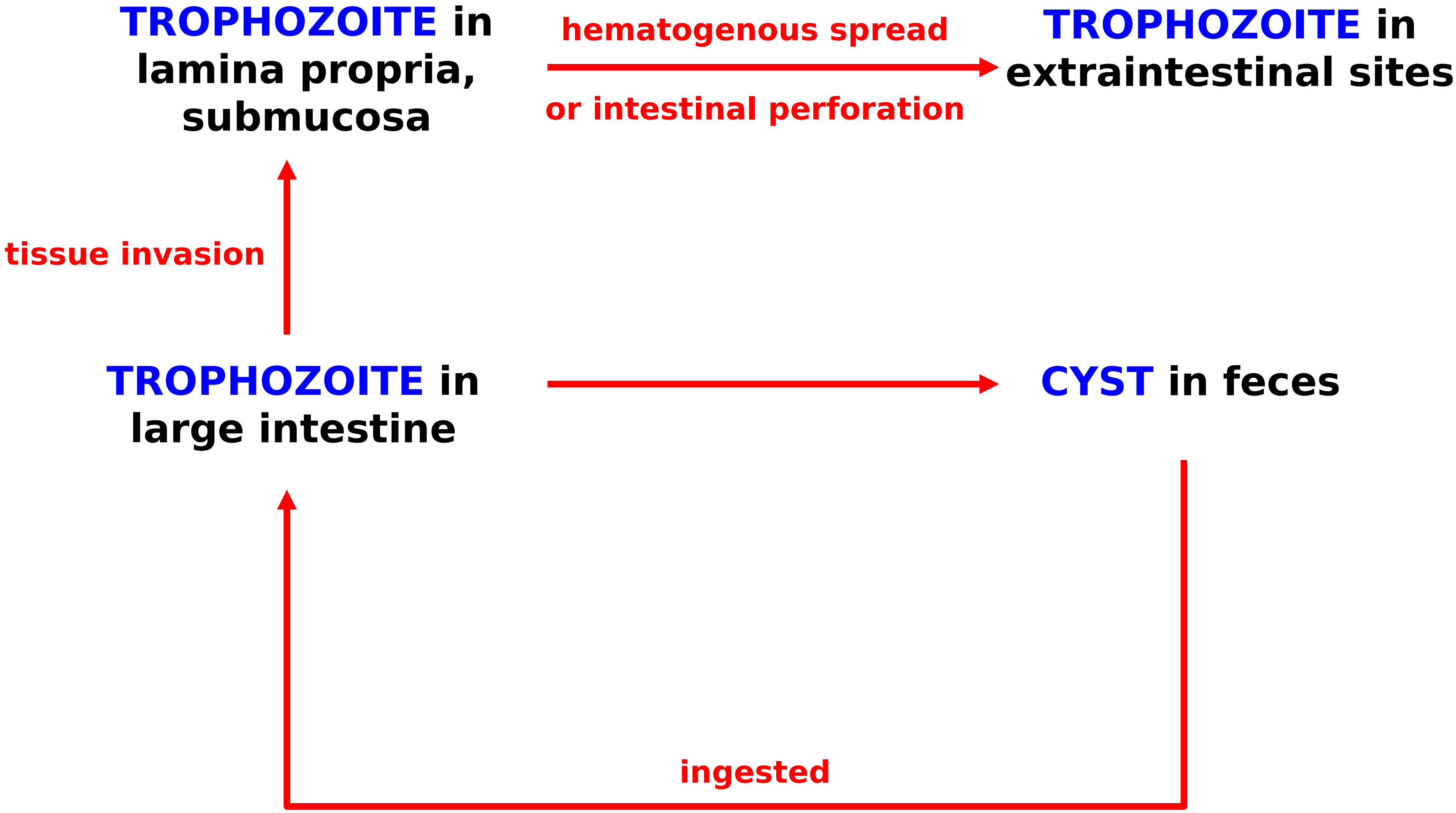
- back to trophozoite of *Entamoeba histolytica*
- back to trophozoite of *Balantidium coli*

B. coli

E. histo-lytica



Life cycle of *Entamoeba histolytica*



TROPHOZOITE in
lamina propria,
submucosa

hematogenous spread
or intestinal perforation

TROPHOZOITE in
extraintestinal sites

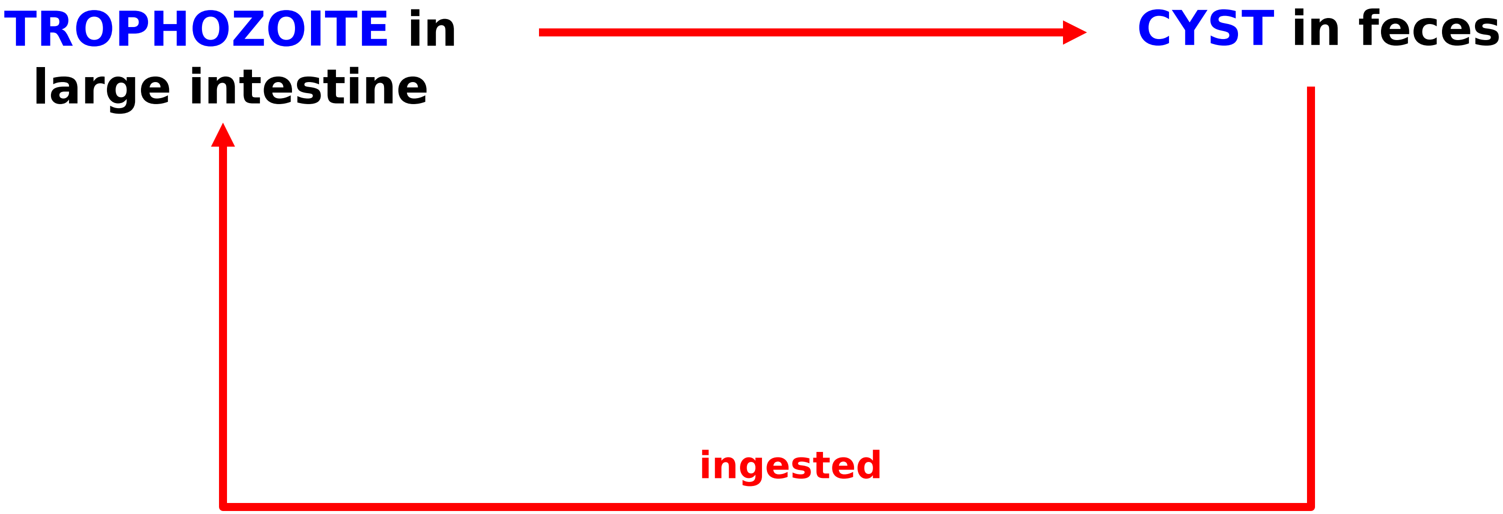
tissue invasion

TROPHOZOITE in
large intestine

CYST in feces

ingested

Life cycle of *Entamoeba coli*

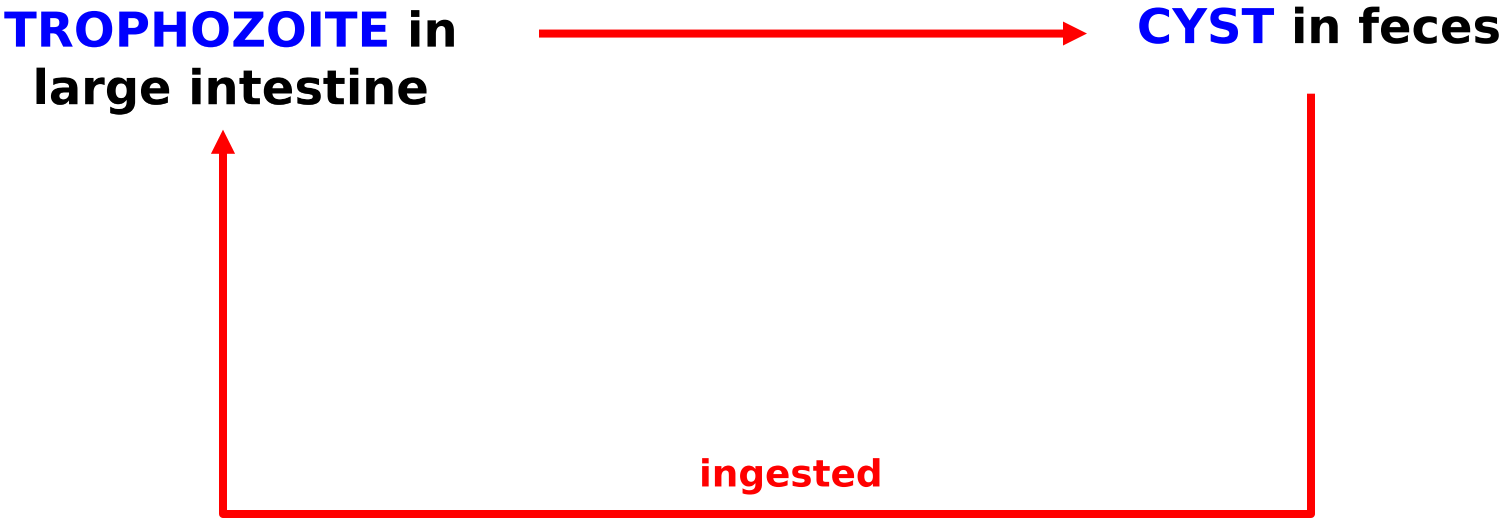


TROPHOZOITE in large intestine

CYST in feces

ingested

Life cycle of *Endolimax nana*

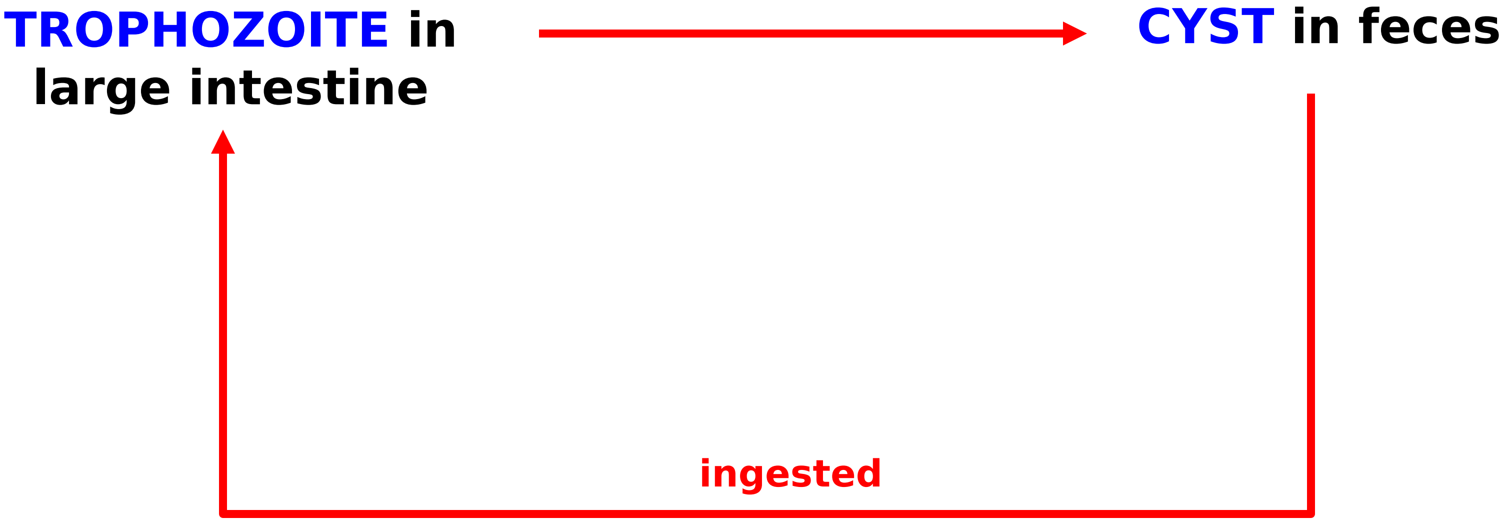


TROPHOZOITE in large intestine

CYST in feces

ingested

Life cycle of *Iodamoeba butschlii*

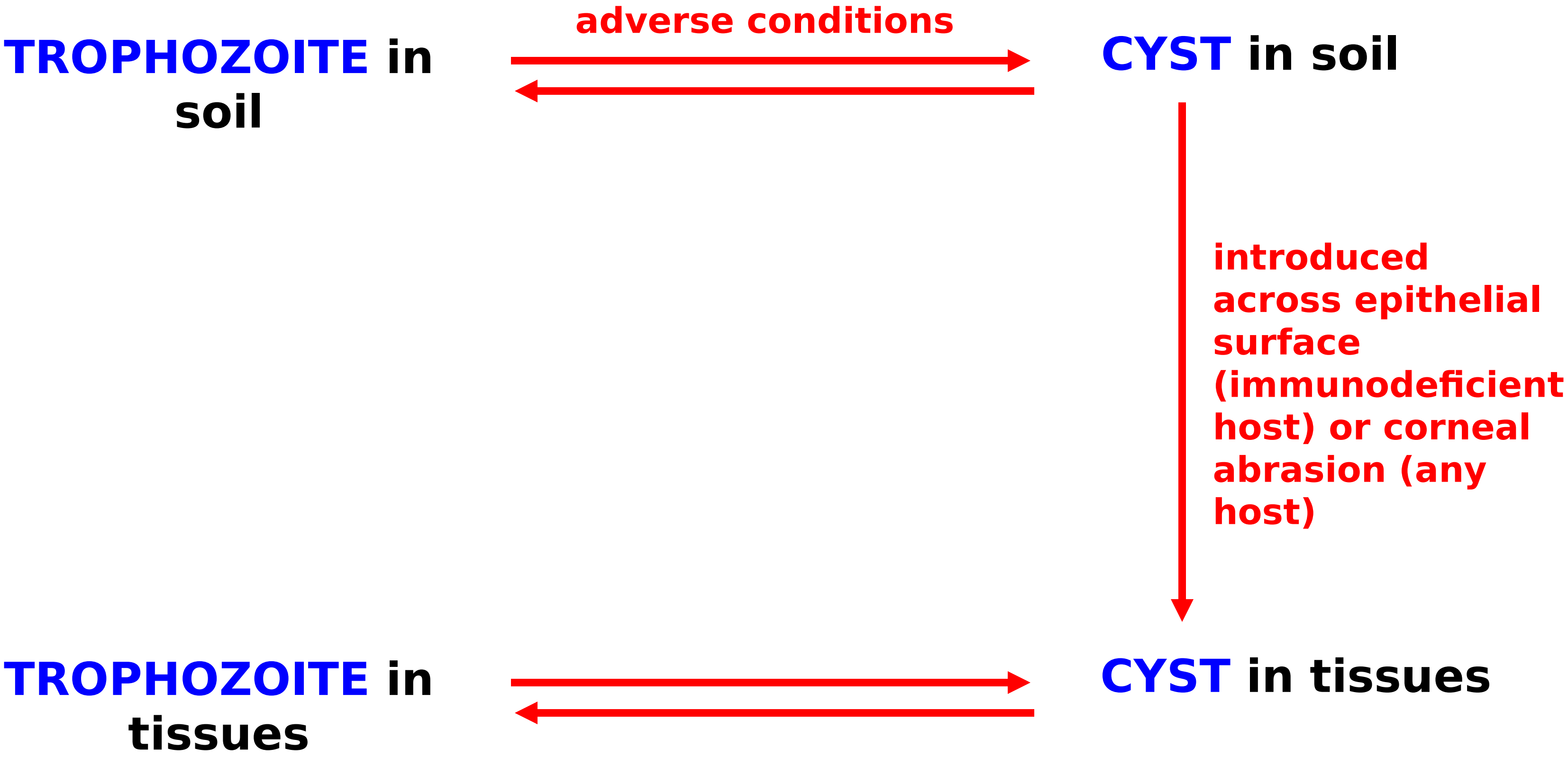


TROPHOZOITE in large intestine

CYST in feces

ingested

Life cycle of *Acanthamoeba* spp.



TROPHOZOITE in soil

adverse conditions

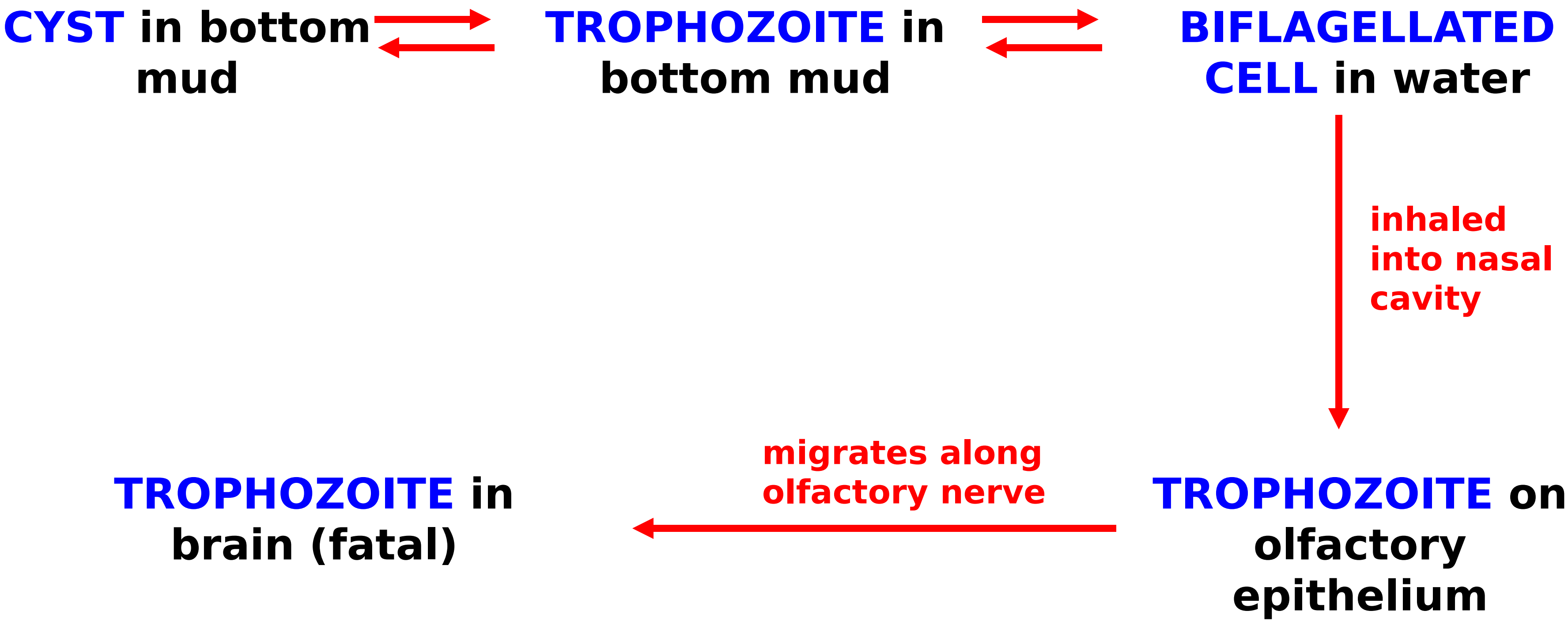
CYST in soil

introduced across epithelial surface (immunodeficient host) or corneal abrasion (any host)

TROPHOZOITE in tissues

CYST in tissues

Life cycle of *Naegleria fowleri*



CYST in bottom mud

TROPHOZOITE in bottom mud

BIFLAGELLATED CELL in water

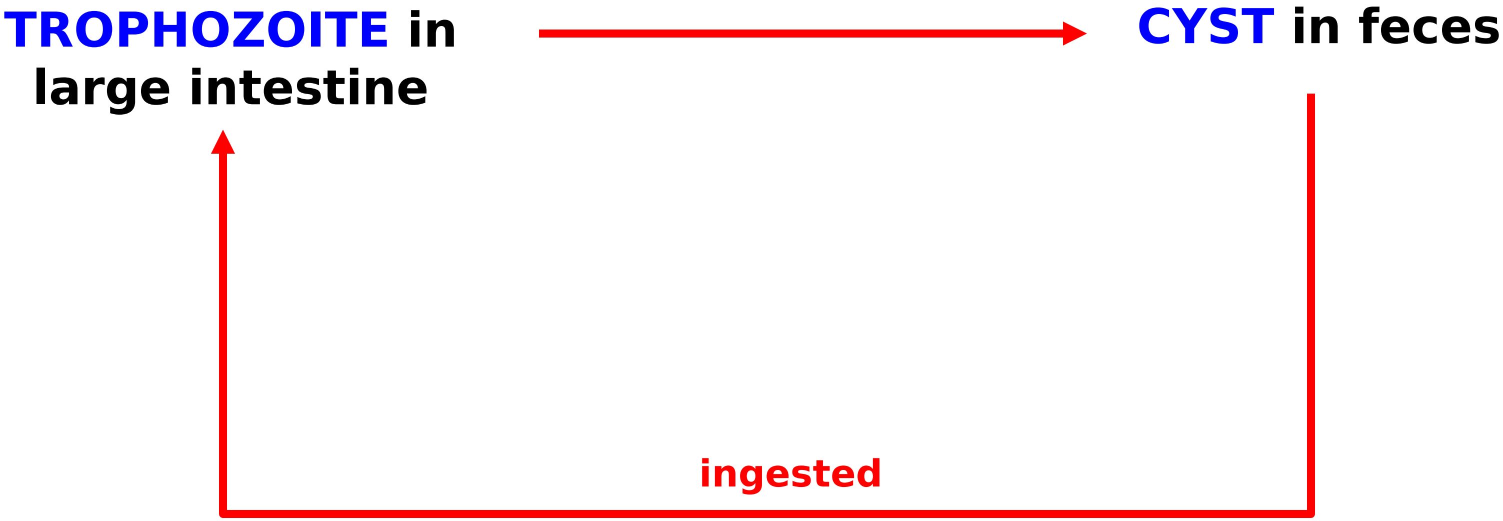
inhaled into nasal cavity

TROPHOZOITE on olfactory epithelium

migrates along olfactory nerve

TROPHOZOITE in brain (fatal)

Life cycle of *Balantidium coli*



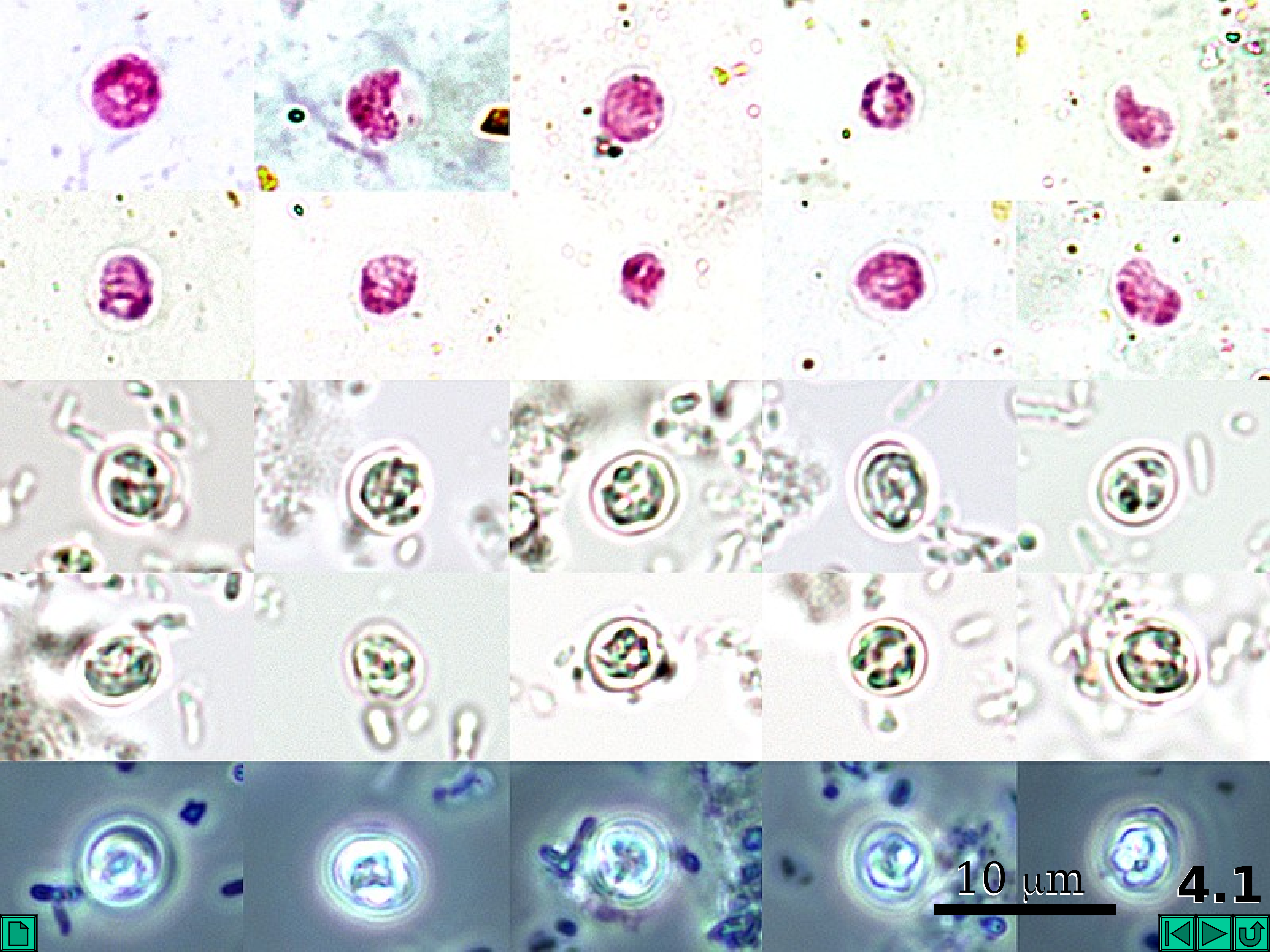
TROPHOZOITE in large intestine

CYST in feces

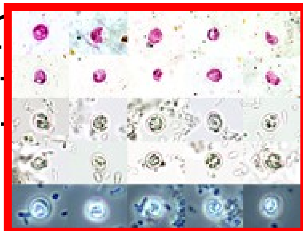
ingested

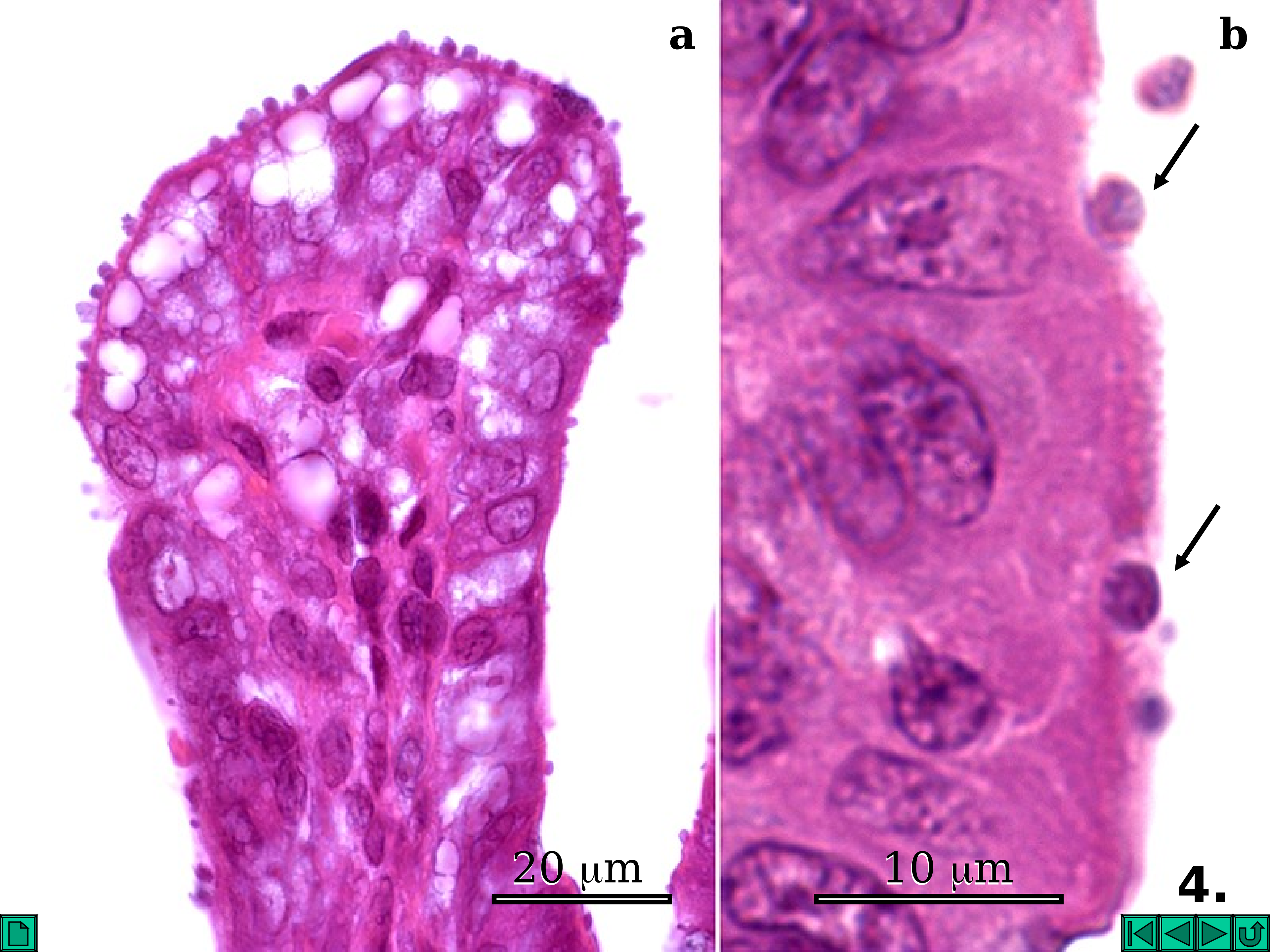
4. Spore-Forming Tissue Parasites

- Oocysts of *Cryptosporidium parvum*
- Intestinal cryptosporidiosis
- Oocysts of *Cyclospora cayetanensis*
- Oocysts of *Isospora belli*
- Tachyzoites of *Toxoplasma gondii*
- Zoitocysts of *Toxoplasma gondii* in brain
- Enteroepithelial cycle of *Toxoplasma gondii*
- Muscle sarcocysts of *Sarcocystis* sp.
- Microsporidian spores
- *Pneumocystis carinii*, lung smear


10 µm

4.1 Oocysts of *Cryptosporidium parvum,* stool smear. First 2 rows, trichrome stain. Second two rows, unstained wet mount viewed with brightfield optics. Bottom row, phase contrast. Cryptosporidiosis is a major cause of diarrheal disease in developing countries, and has increasingly been recognized as a health problem in the United States. Due to its widespread occurrence in animals and resistance of oocysts to chlorination (including household bleach), it is a threat to public water supplies. Symptoms range from severe diarrhea for up to 2 weeks in previously healthy people to life-threatening diarrhea in immunocompromised patients. Oocysts contain 4 sporozoites when passed in the feces, and are immediately infective, with som rupturing in the intestine and reinfecting epit cells (autoinfection). A water-borne outbreak

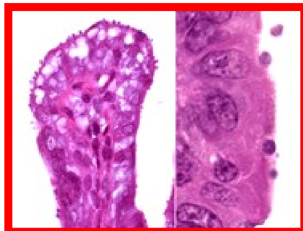


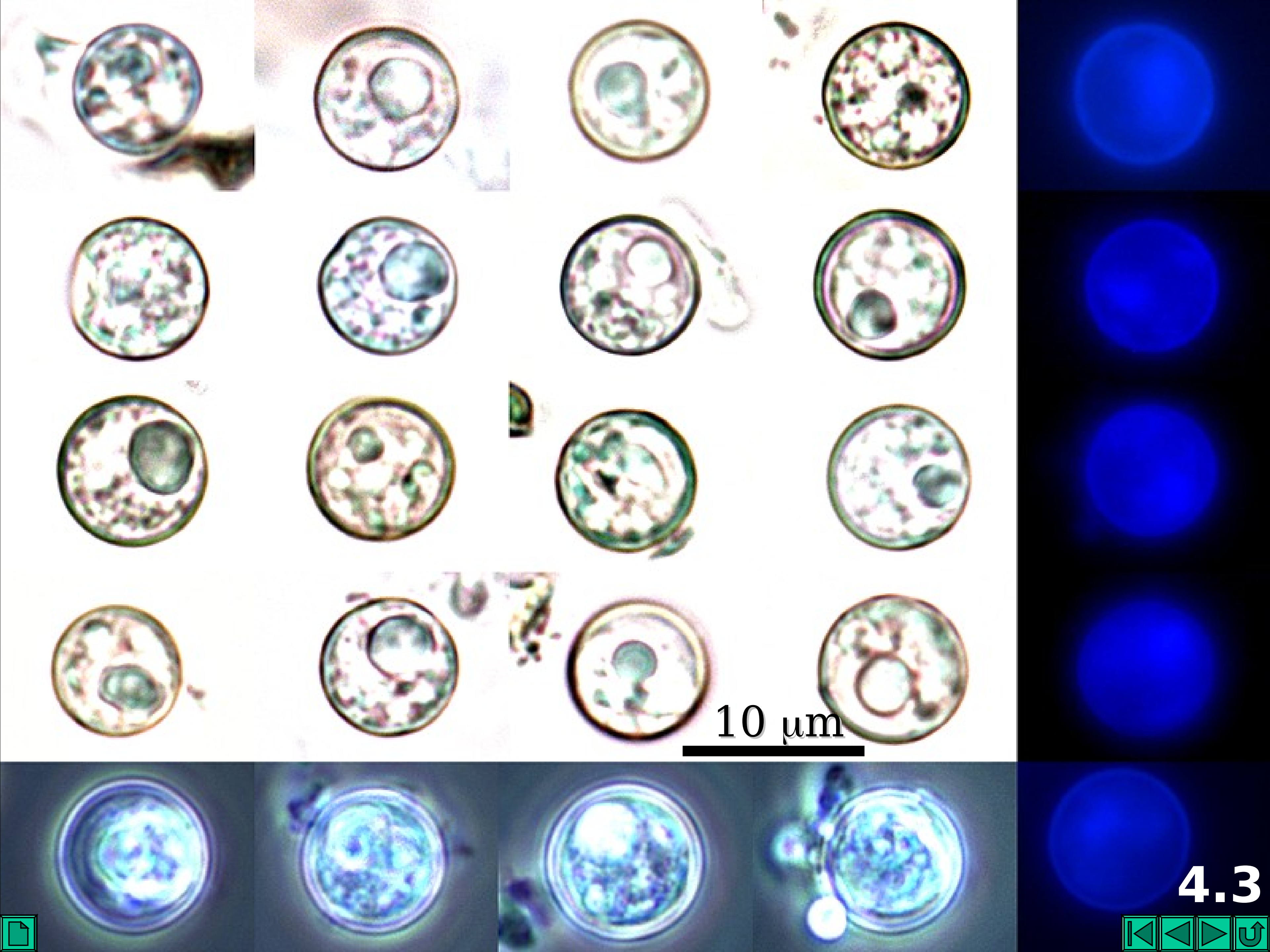

a
b
20 µm
10 µm

4.

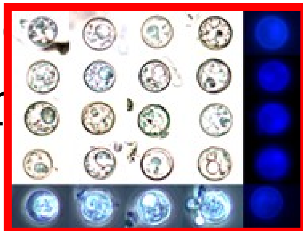
4.2 Cryptosporidiosis: *Cryptosporidium parvum* infection in the intestinal epithelium of a monkey. **a.** Heavily infected intestinal villus. Villus atrophy and crypt hyperplasia are the two prominent histopathological features of cryptosporidiosis. Note the numerous parasites in the brush border of the enterocytes, and vacuolization of cells at the tip of the villus. **b.** Higher magnification view of developing oocysts (arrows). Although the parasites appear to be on the surface of the enterocytes, they are actually enclosed by the plasma membrane of the microvilli, and hence are intracellular.

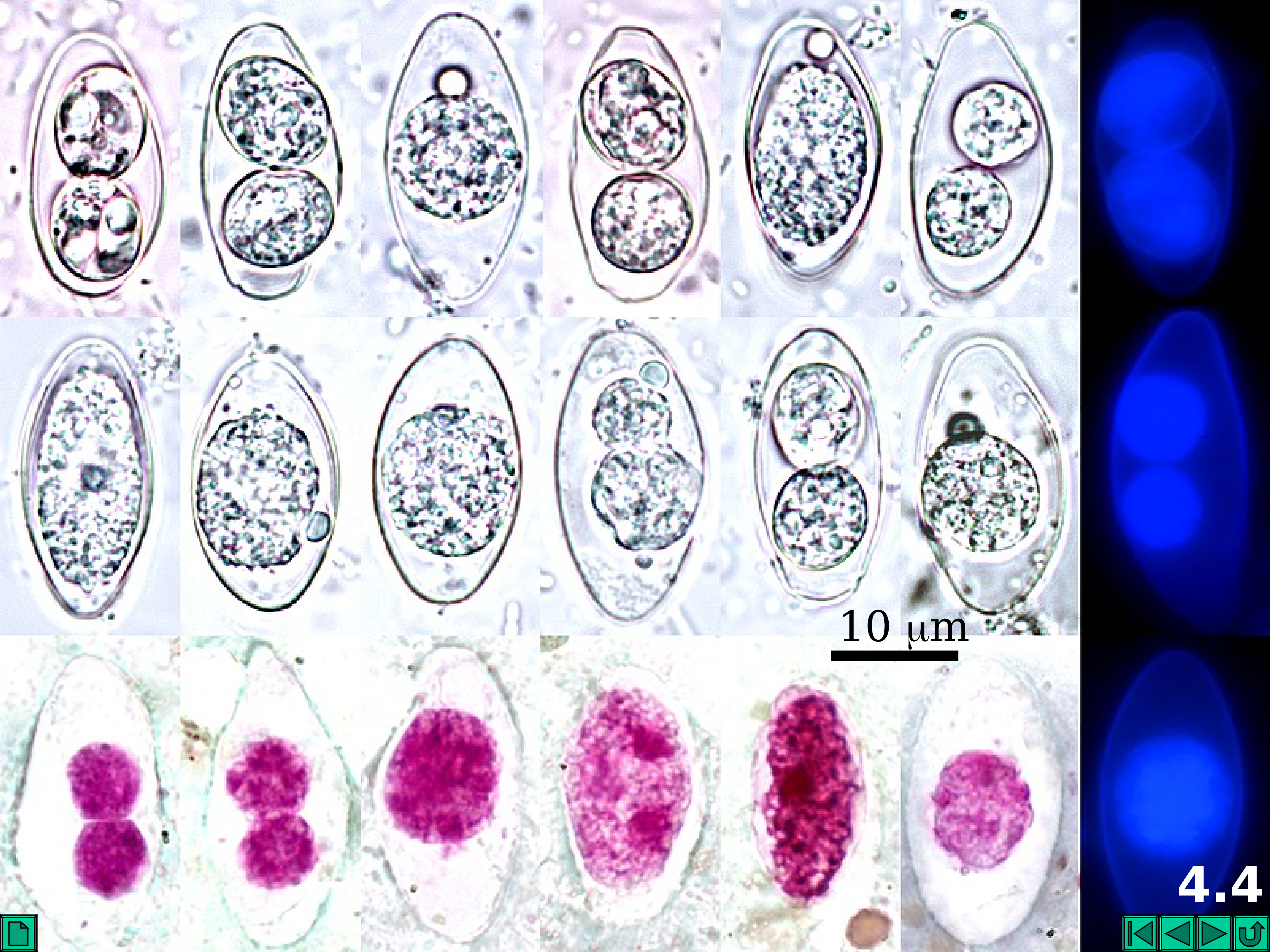
- back to oocysts of *Cryptosporidium parvum*



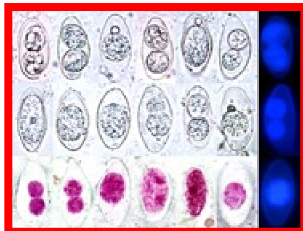

10 µm

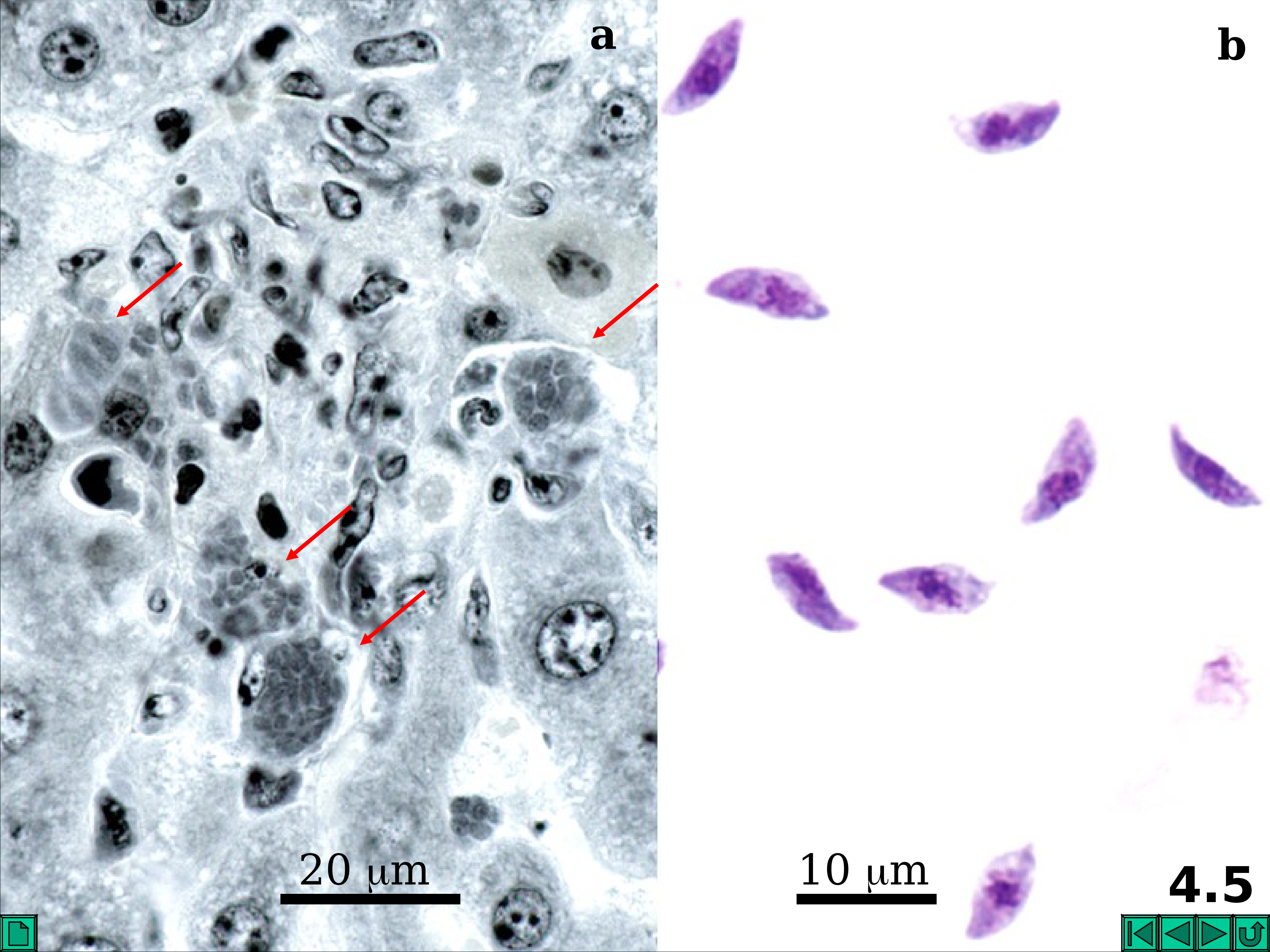
4.3 Oocysts of *Cyclospora cayetanensis,* wet mount. First 4 rows and columns, brightfield optics; 5th row, phase contrast. This coccidian has been implicated in several outbreaks of diarrhea in the U.S. following the consumption of fresh produce (raspberries from Guatemala, mesclun lettuce, basil). Symptoms range from mild to fever, nausea, and diarrhea, which can be protracted and severe (e.g., 35 stools/day). Therefore, infections in AIDS patients are serious. The oocyst is unsporulated when passed in the feces, producing 2 sporocysts, each with 2 sporozoites, after 7-12 days, depending on the temperature. Because the oocyst, like that of *Isospora belli*, is autofluorescent, diagnosis can be made by scanning wet mounts with a fluoresc microscope equipped with a 340-380 nm filter (right column).




10 µm

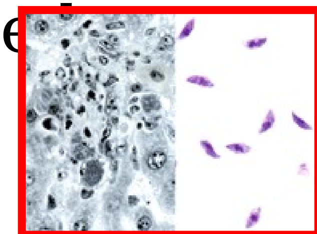
4.4 Oocysts of *Isospora belli*. First 2 rows, unstained wet mount viewed with brightfield optics. Third row, trichrome stain. Oocysts are passed out in the feces unsporulated, containing one cell (sporont) or two cells (sporoblasts). Each sporoblast develops outside the host into a sporocyst with 4 sporozoites (8 sporozoites/oocyst). As with *Cyclospora cayetanensis*, unstained oocysts of *I. belli* fluoresce when viewed with ultraviolet light (right column). Human infections with *I. belli* occur mainly in the tropics, and can cause fever and severe diarrhea, which may be fatal in AIDS patients.

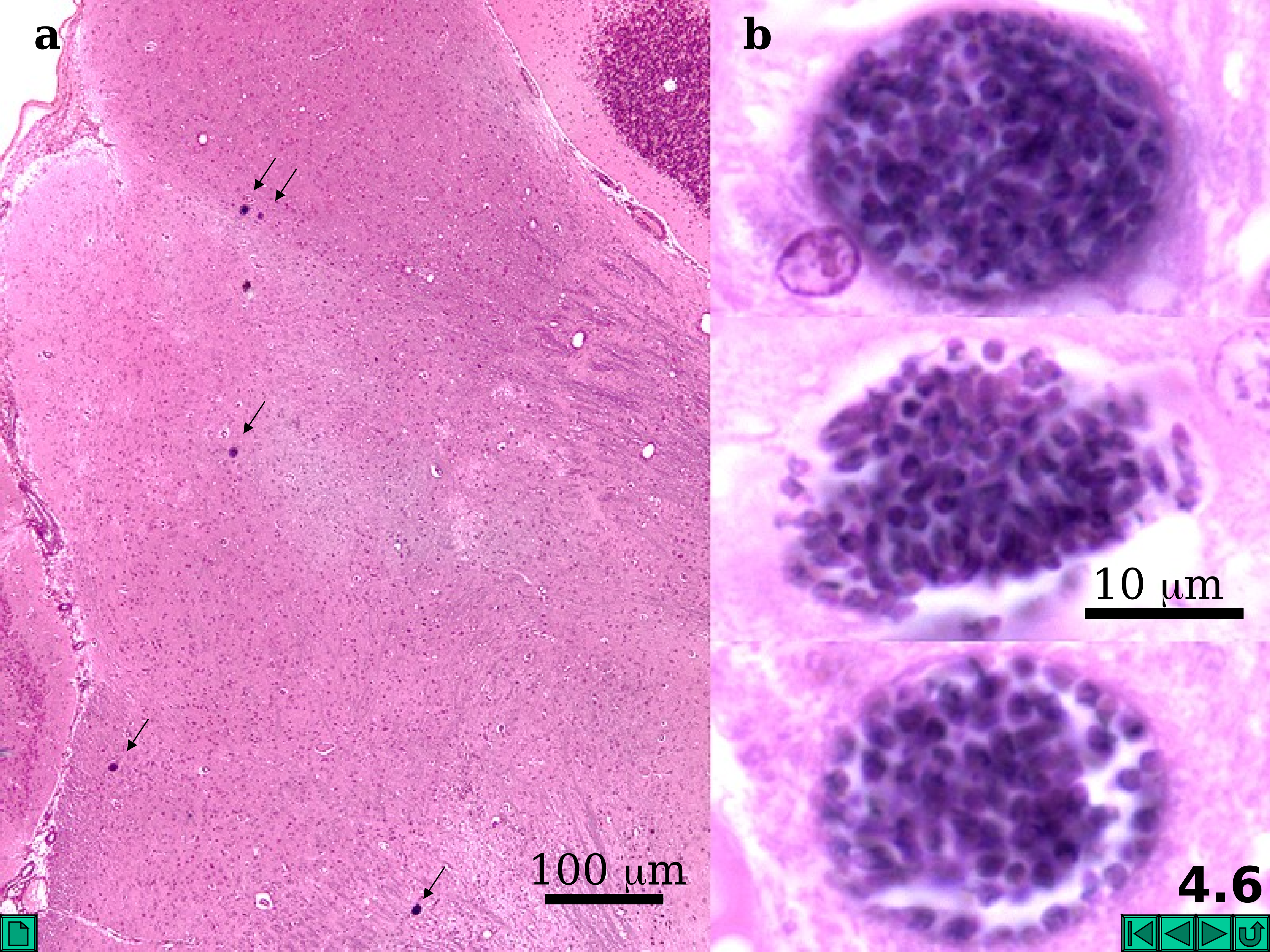



a
b
20 µm
10 µm

4.5

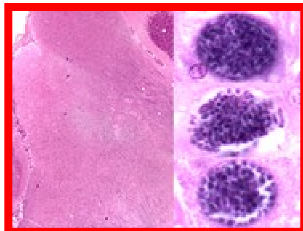
4.5 Extraintestinal cycle of *Toxoplasma gondii* in the mouse. When an intermediate host, which could be almost any mammal or bird, ingests oocysts (containing sporozoites) from cat feces or zoitocysts (containing bradyzoites) in the tissues of another intermediate host, repeated, rapid cycles of schizogony occur, releasing merozoites (tachyzoites), which infect cells in a wide variety of tissues. **a.** Histological section of liver, showing several infected cells (arrows) surrounding a necrotic area. **b.** Smear of peritoneal fluid, showing tachyzoites. This stage of the infection usually produces mild, if any, symptoms in healthy persons, but can be lethal in immunocompromised individuals (acquired toxoplasmosis), and can cause severe damage to the fetus if transmitte transplacentally (congenital toxoplasmosis).

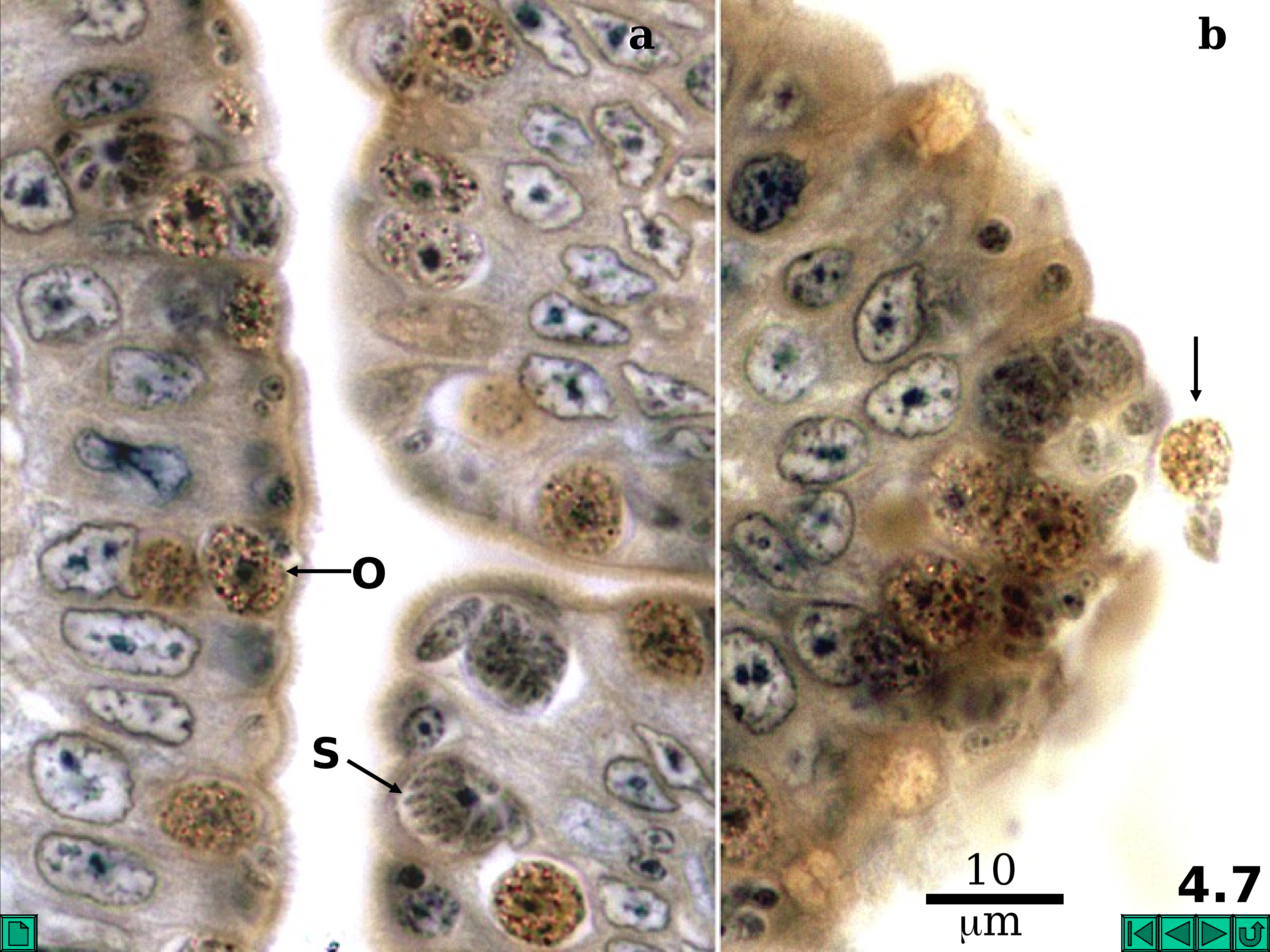



a
b
100 μm
10 μm

4.6

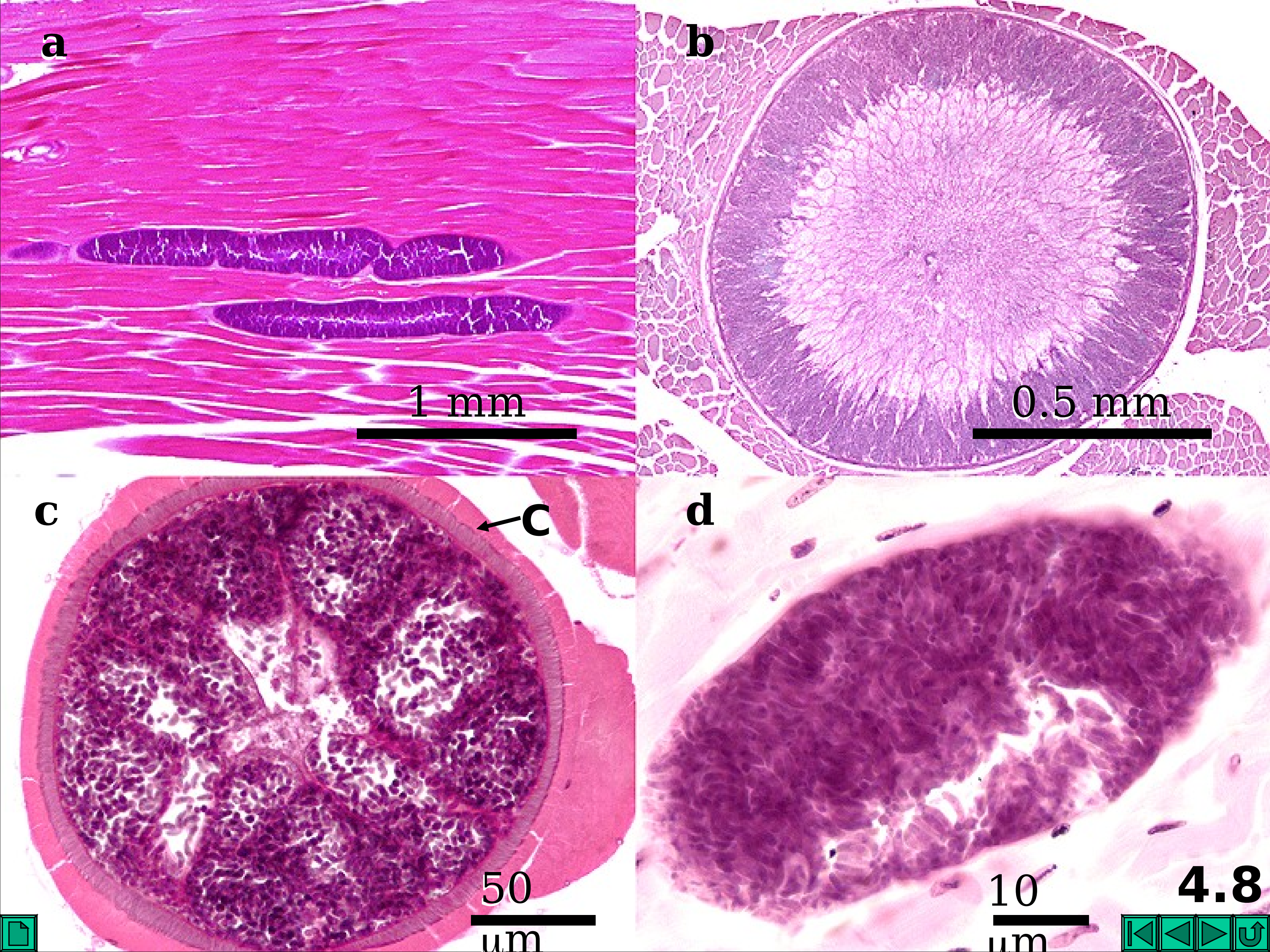
4.6 Histological sections of zoitocysts of *Toxoplasma gondii* in the brain of a mouse. The proliferation of tachyzoites elicits an immune response that slows down schizogony, resulting in accumulations of slowly-dividing merozoites, called bradyzoites, within an infected cell. These intracellular accumulations, known as zoitocysts, may persist for years in nervous tissue. Ingestion of zoitocysts will initiate the enteroepithelial cycle in cats, and the extraintestinal cycle in birds and mammals. **a.** Low magnification view of a portion of brain, showing minute zoitocysts (arrows). **b.** Higher magnification of 3 zoitocysts, showing bradyzoites.



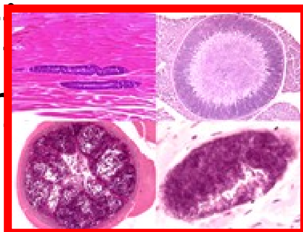


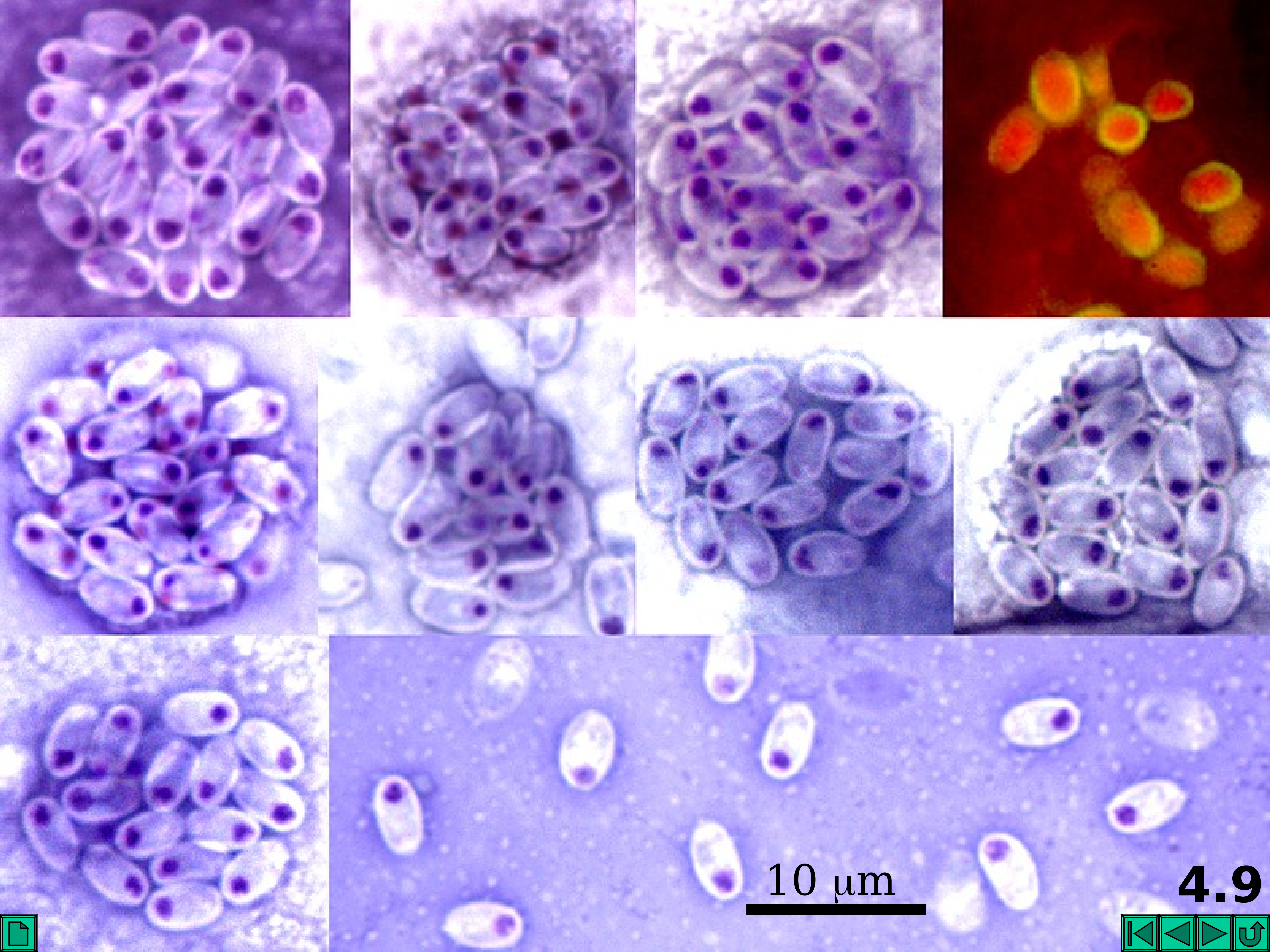
4.7

4.7 Enteroepithelial cycle of *Toxoplasma gondii* in the epithelial lining of the cat intestine, histological section. **a.** Intestinal epithelial cells infected with oocysts (O) and schizonts (S) containing merozoites. **b.** Oocyst (arrow) being released into the lumen from an epithelial cell. Ingestion of oocysts (containing sporozoites) or intermediate hosts infected with tachyzoites or zoitocysts (containing bradyzoites) results in schizogony and sexual reproduction, leading to the production of oocysts. This sexual cycle occurs only in the cat, whereas in intermediate hosts, only asexual schizogony occurs.


a
b
1 mm
0.5 mm
c
C
d
50 µm
10 µm

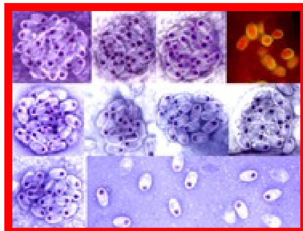
4.8 Histological sections of muscle cysts (sarcocysts) of *Sarcocystis* spp. Members of this genus undergo an obligately heteroxenous life cycle, with sexual reproduction occurring in a carnivore, and several cycles of schizogony occurring in a herbivore. Because the oocyst easily ruptures in the digestive tract of the definitive host, usually only sporocysts (packets of sporozoites) are released in the feces. Humans can serve as definitive host for some species and intermediate host for others. **a.** Low magnification view of longitudinal sections of 2 sarcocysts (Miescher's tubules) in skeletal muscle. **b.** Cross section of a mature sarcocyst. Bradyzoites are confined to the periphery. **c.** Cross section of a developing sarcocyst, show bradyzoites and developing internal septa. Th cyst wall has radial fibers, called cytophanere

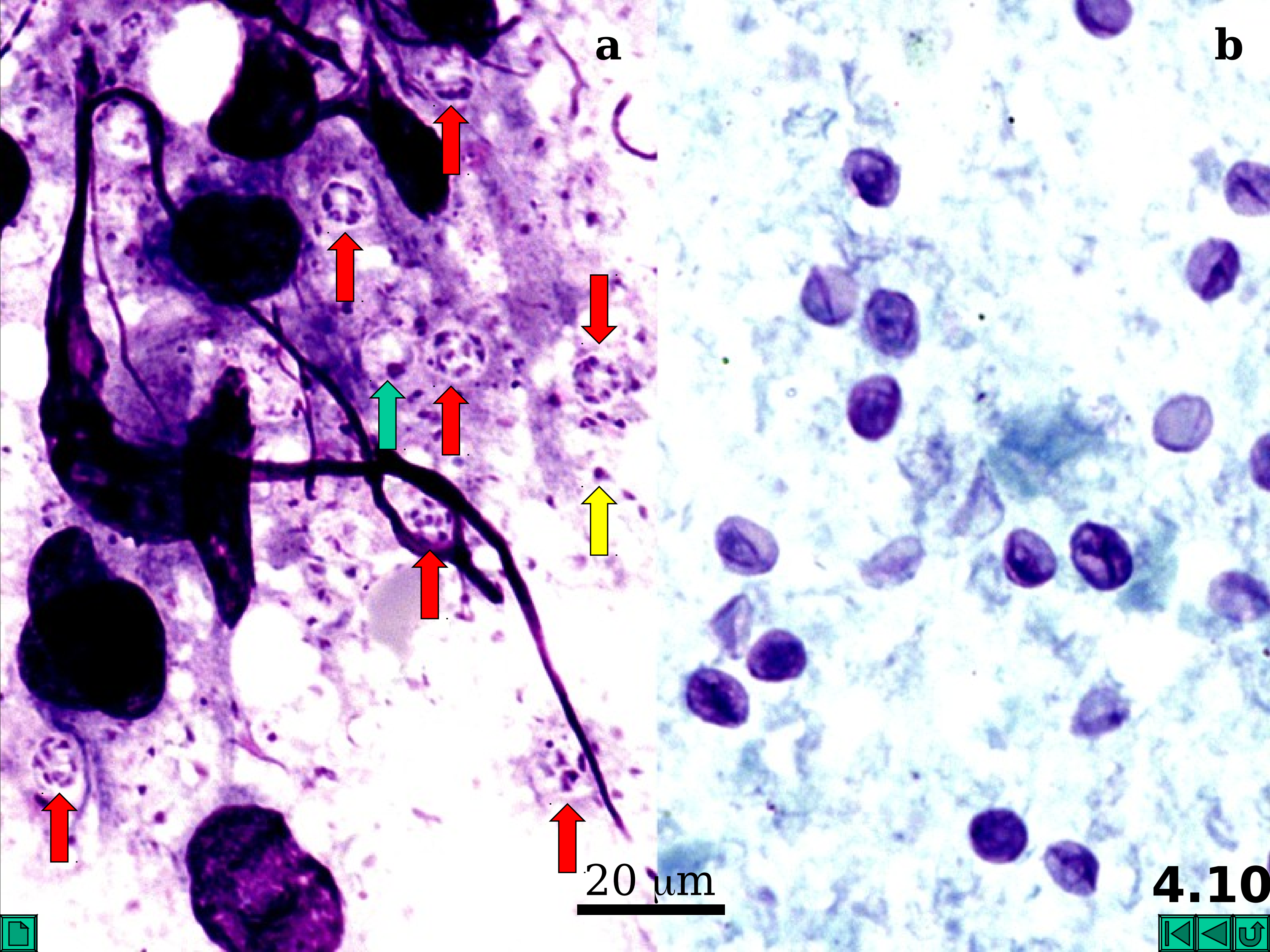



10 µm

4.9 Spores of a microsporidian, *Pleistophora husseyi,* in a smear of tissue from an infected snail (*Physa virgata*). Parasites of everything from other protozoa to mammals, microsporidia can inflict economic losses on the silkworm and honeybee industries, and several species can cause serious disease in AIDS patients. These organisms are unrelated to the apicomplexan sporozoans in Figures 4.1 - 4.8. However, as intracellular protozoa that form spores, they are most conveniently included here. Top right photo shows spores stained with Uvitex 2-B and viewed with UV light, demonstrating the presence of chitin in the spore wall (scanned from a 35-mm slide).

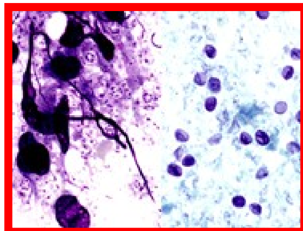
Top right photo from J.T. Sullivan, *Electronic Atlas of Parasitology, 1.0.* Copyright © 1999 McGraw-Hill, Inc., Dubuque, IA. Reprinted by permission.



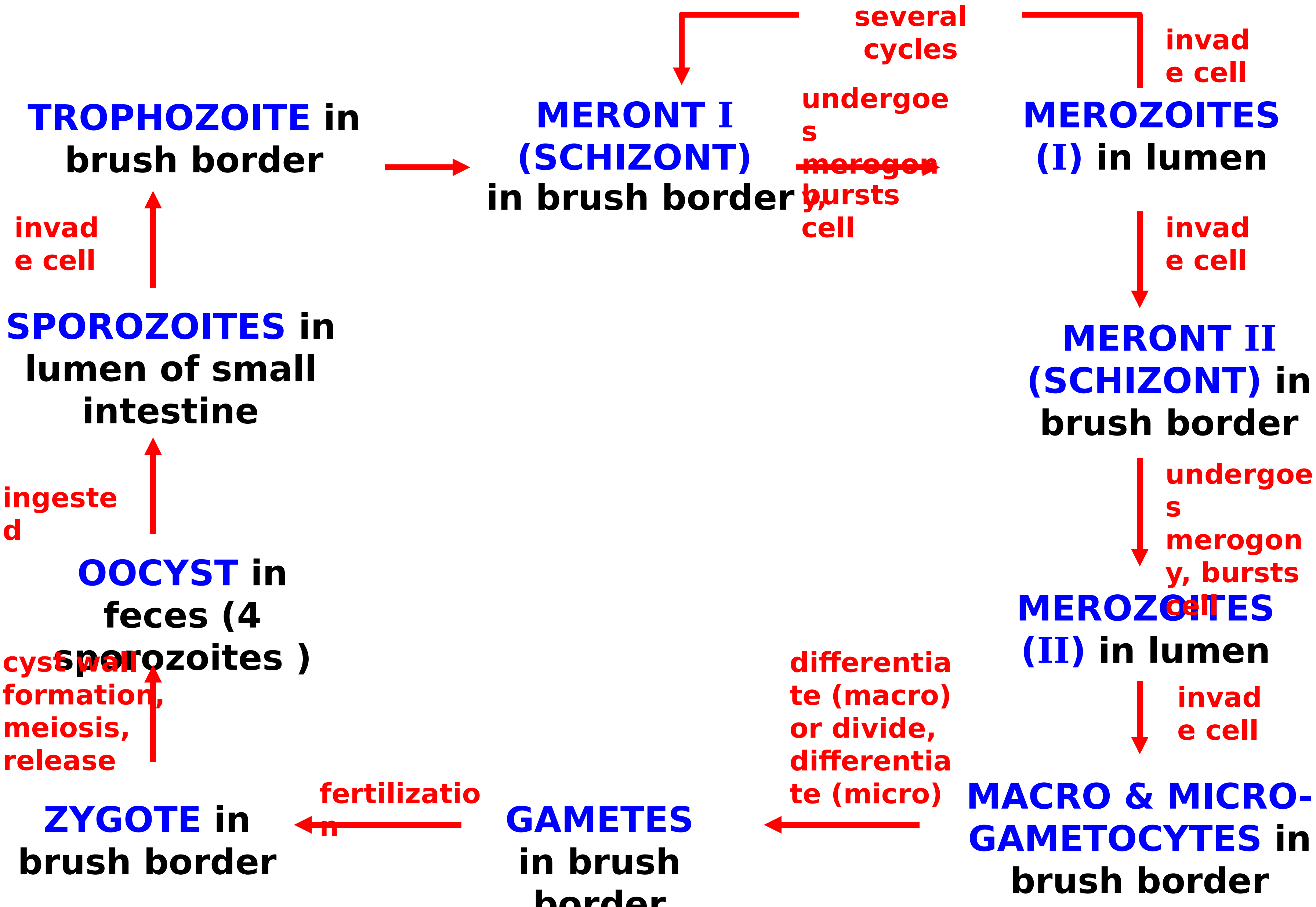


4.10

4.10 *Pneumocystis carinii* in a smear of infected rat lung. *P. carinii* is now considered to be fungus, rather than a protozoan. Life threatening pneumonia develops in immunocompromised individuals infected with this organism. **a.** Smear stained with Giemsa. The life cycle is not fully known, but precysts (green arrow), cysts with 8 intracystic bodies (red arrow), and amoeboid trophozoites (yellow arrow) have been described. **b.** Smear stained with toluidine blue, showing cyst wall.



Life cycle of *Cryptosporidium parvum*



TROPHOZOITE in brush border

MERONT I (SCHIZONT) in brush border

undergoes merogony, bursts cell

several cycles

MEROZOITES (I) in lumen

invade cell

invade cell

MERONT II (SCHIZONT) in brush border

undergoes merogony, bursts cell

MEROZOITES (II) in lumen

invade cell

MACRO & MICRO-GAMETOCYTES in brush border

differentiate (macro) or divide, differentiate (micro)

GAMETES in brush border

fertilization

ZYGOTE in brush border

cyst wall formation, meiosis, release

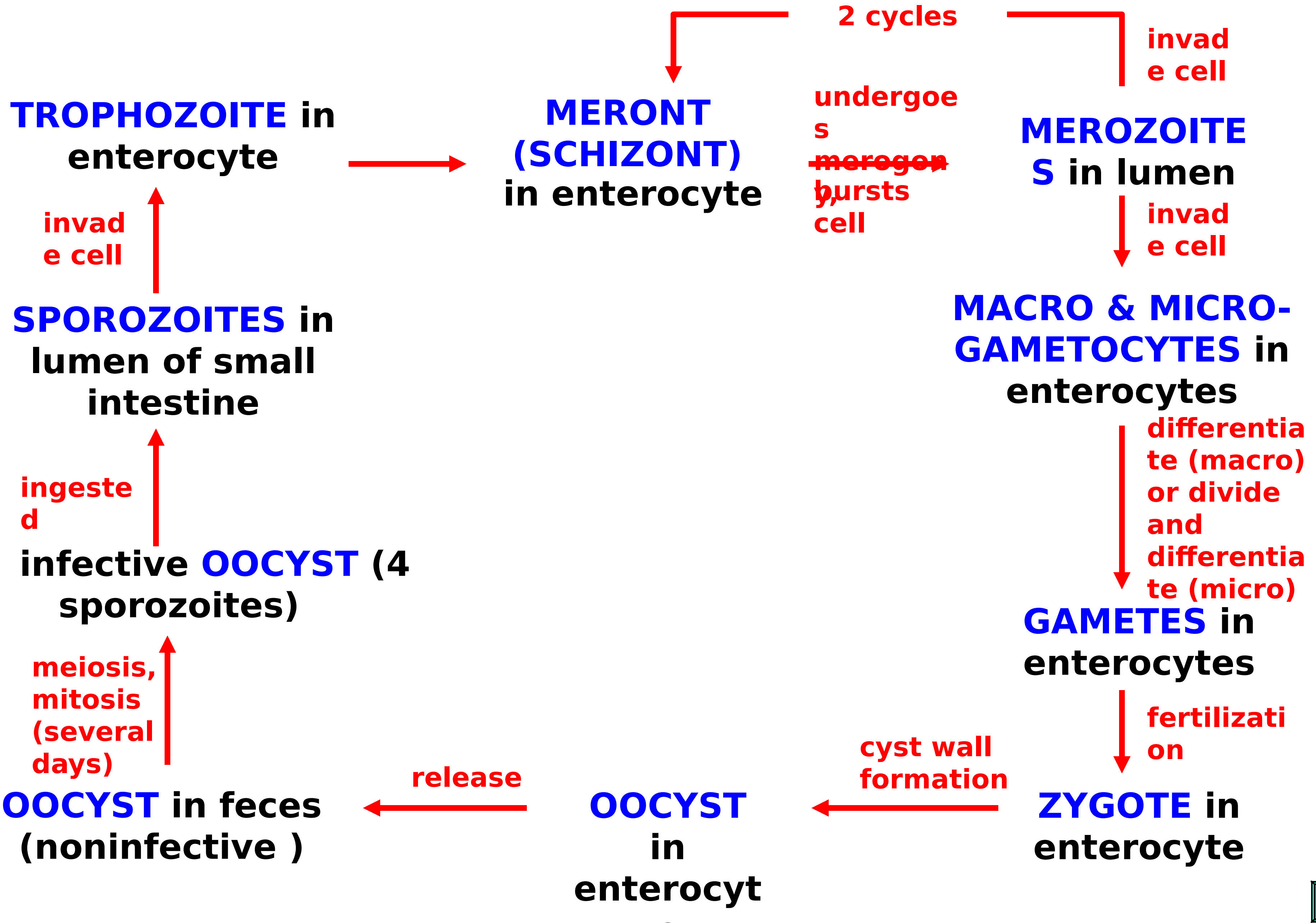
OOCYST in feces (4 sporozoites)

ingested

SPOROZOITES in lumen of small intestine

invade cell

Life cycle of *Cyclospora cayetanensis*



TROPHOZOITE in enterocyte

MERONT (SCHIZONT) in enterocyte

2 cycles

undergoes merogony, bursts cell

invade cell

MEROZOITES in lumen

invade cell

MACRO & MICRO-GAMETOCYTES in enterocytes

differentiate (macro) or divide and differentiate (micro)

GAMETES in enterocytes

fertilization

ZYGOTE in enterocyte

cyst wall formation

OOCYST in enterocyt

release

OOCYST in feces (noninfective)

meiosis, mitosis (several days)

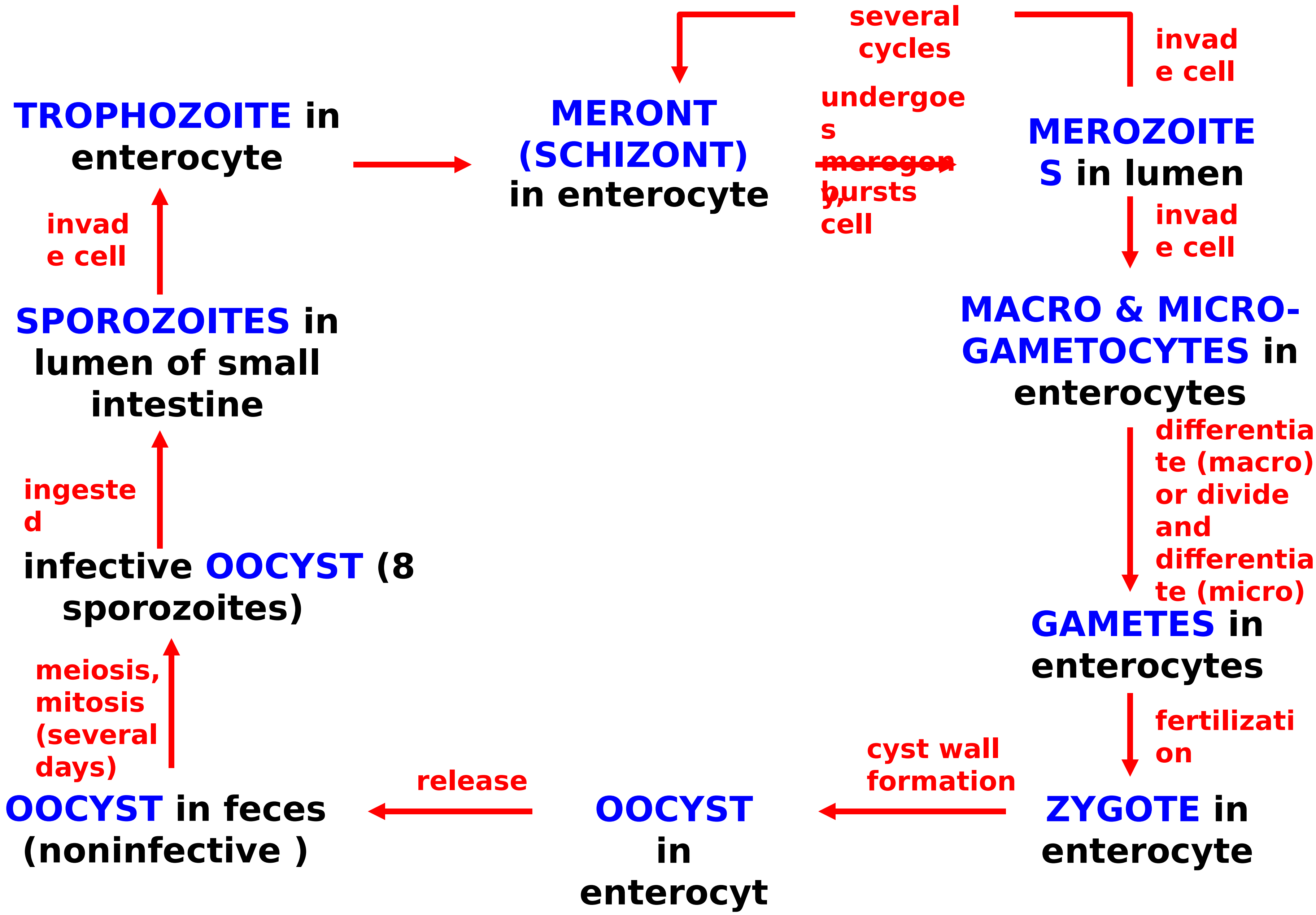
infective **OOCYST** (4 sporozoites)

ingested

SPOROZOITES in lumen of small intestine

invade cell

Life cycle of *Isospora belli*



several cycles

TROPHOZOITE in enterocyte

MERONT (SCHIZONT) in enterocyte

undergoes merogony, bursts cell

invade cell

MEROZOITES in lumen

invade cell

invade cell

SPOROZOITES in lumen of small intestine

MACRO & MICRO-GAMETOCYTES in enterocytes

differentiate (macro) or divide and differentiate (micro)

ingested

infective **OOCYST** (8 sporozoites)

GAMETES in enterocytes

meiosis, mitosis (several days)

fertilization

cyst wall formation

release

OOCYST in feces (noninfective)

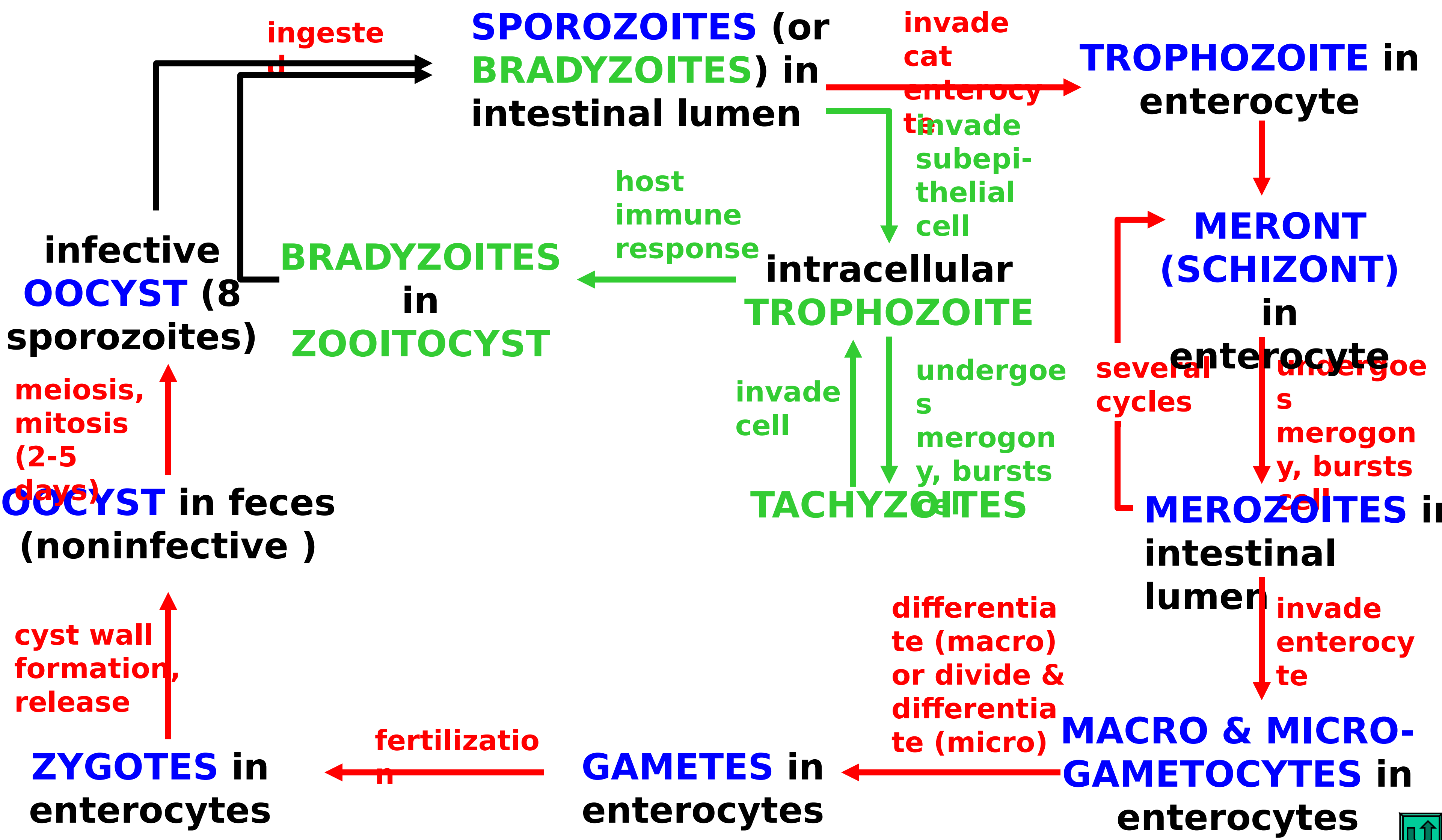
OOCYST in enterocyt

ZYGOTE in enterocyte

Life cycle of *Toxoplasma gondii*

↔ **Enteroepithelial cycle** (cat only)

↔ **Extraintestinal cycle** (any mammal, birds)



SPOROZOITES (or **BRADYZOITES**) in intestinal lumen

ingested

invade cat enterocyte

TROPHOZOITE in enterocyte

MERONT (SCHIZONT) in enterocyte

undergoes merogony, bursts cell

several cycles

MEROZOITES i intestinal lumen

invade enterocyte

MACRO & MICRO-GAMETOCYTES in enterocytes

differentiate (macro) or divide & differentiate (micro)

GAMETES in enterocytes

fertilization

ZYGOTES in enterocytes

cyst wall formation, release

OOCYST in feces (noninfective)

meiosis, mitosis (2-5 days)

infective **OOCYST** (8 sporozoites)

invade subepithelial cell

intracellular **TROPHOZOITE**

undergoes merogony, bursts cell

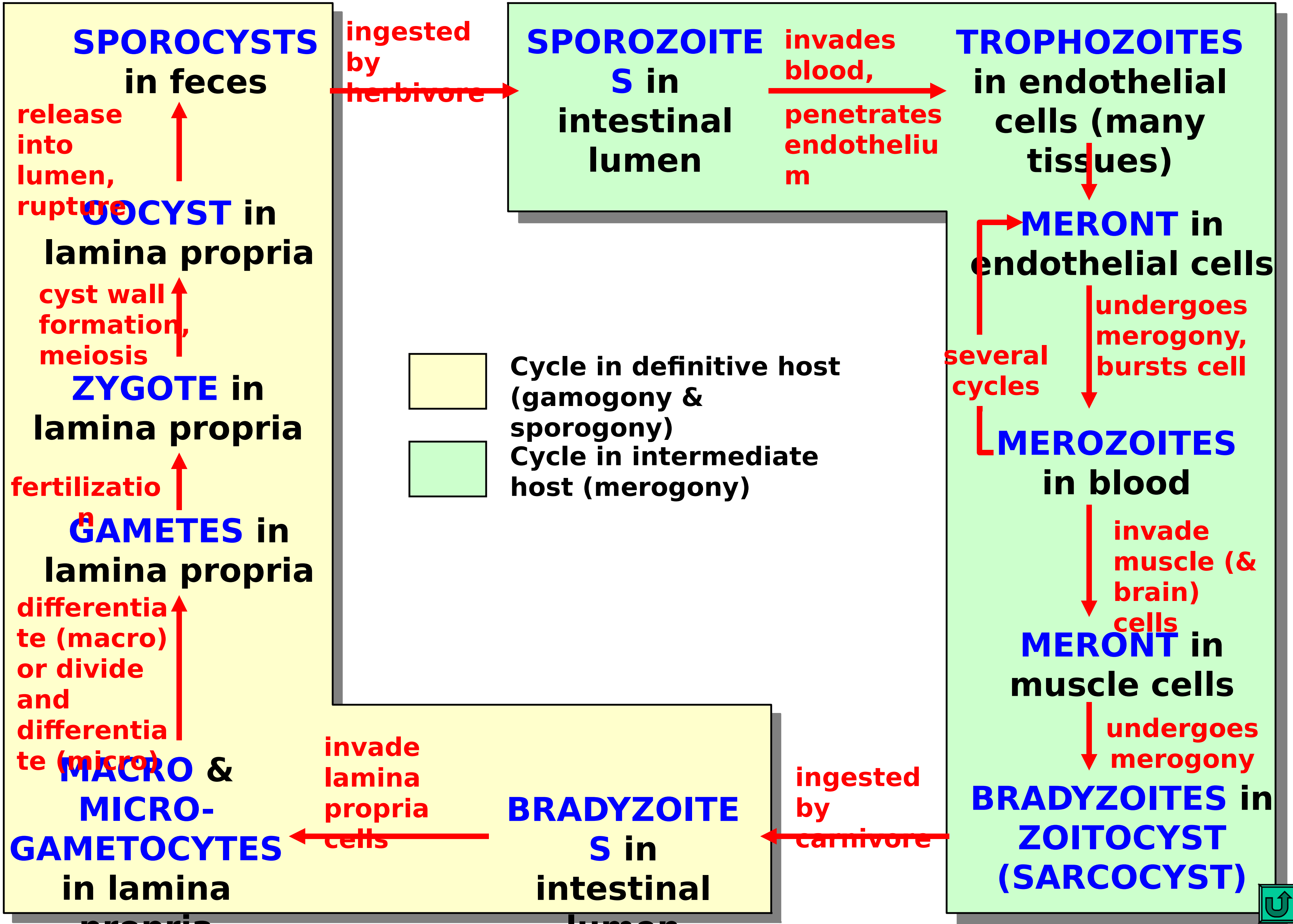
TACHYZOITES

invade cell

host immune response

BRADYZOITES in **ZOOITOCYST**

Life cycle of *Sarcocystis* spp.



SPOROCYSTS in feces

ingested by herbivore

SPOROZOITES in intestinal lumen

invades blood, penetrates endothelium

TROPHOZOITES in endothelial cells (many tissues)

MERONT in endothelial cells

undergoes merogony, bursts cell

several cycles

MEROZOITES in blood

invade muscle (& brain) cells

MERONT in muscle cells

undergoes merogony

BRADYZOITES in **ZOITOCYST (SARCOCYST)**

ingested by carnivore

BRADYZOITES in intestinal lumen

invade lamina propria cells

MACRO & **MICRO-GAMETOCYTES** in lamina propria

differentiate (macro) or divide and differentiate (micro)

GAMETES in lamina propria

fertilization

ZYGOTE in lamina propria

cyst wall formation, meiosis

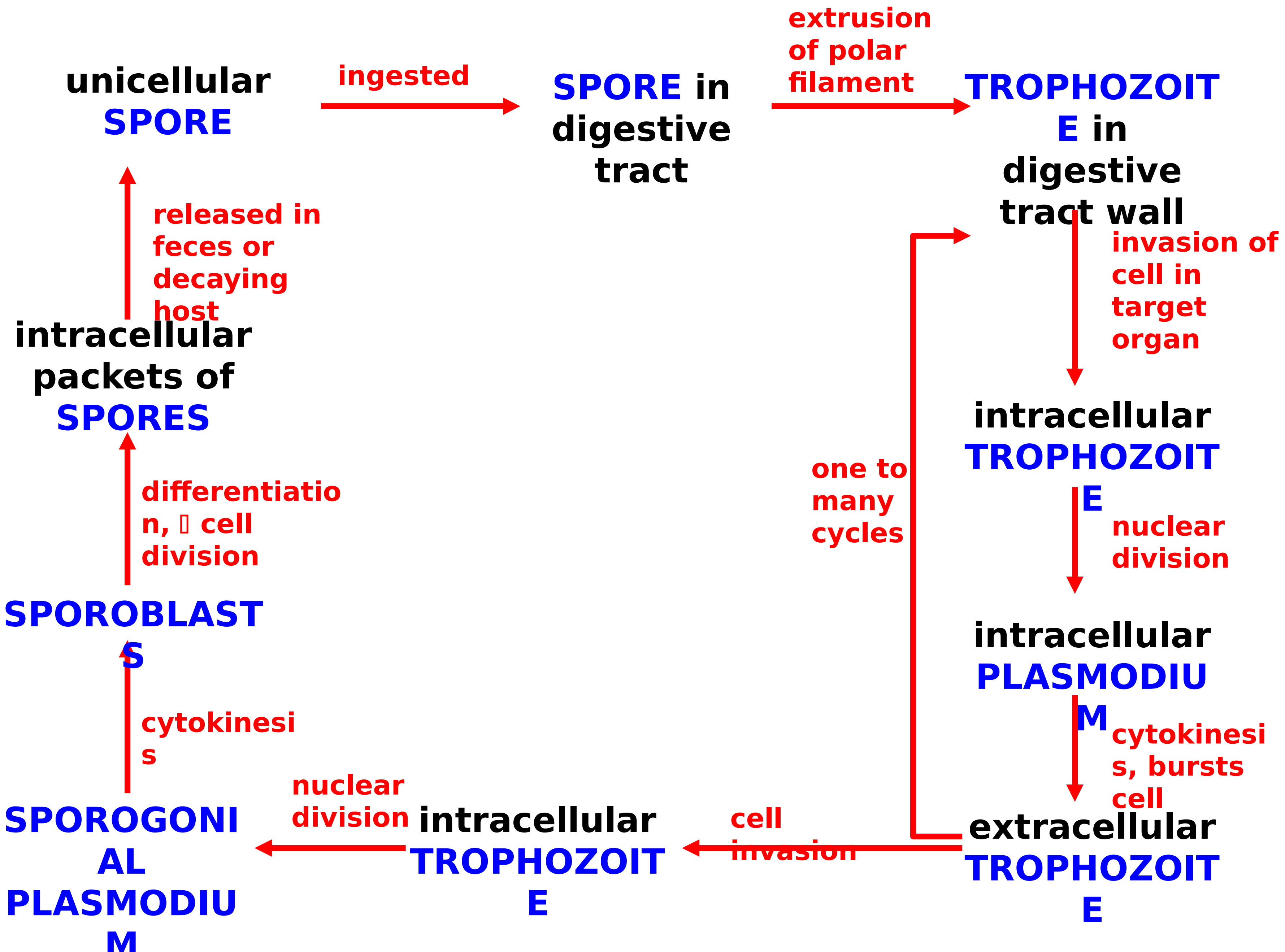
OOCYST in lamina propria

release into lumen, rupture

🟨 Cycle in definitive host (gamogony & sporogony)

🟩 Cycle in intermediate host (merogony)

Generalized microsporidian life cycle



unicellular **SPORE**

ingested

SPORE in digestive tract

extrusion of polar filament

TROPHOZOITE in digestive tract wall

invasion of cell in target organ

intracellular **TROPHOZOITE**

nuclear division

intracellular **PLASMODIUM**

cytokinesis, bursts cell

extracellular **TROPHOZOITE**

one to many cycles

cell invasion

intracellular **TROPHOZOITE**

nuclear division

SPOROGONIAL PLASMODIUM

cytokinesis

SPOROBLASTS

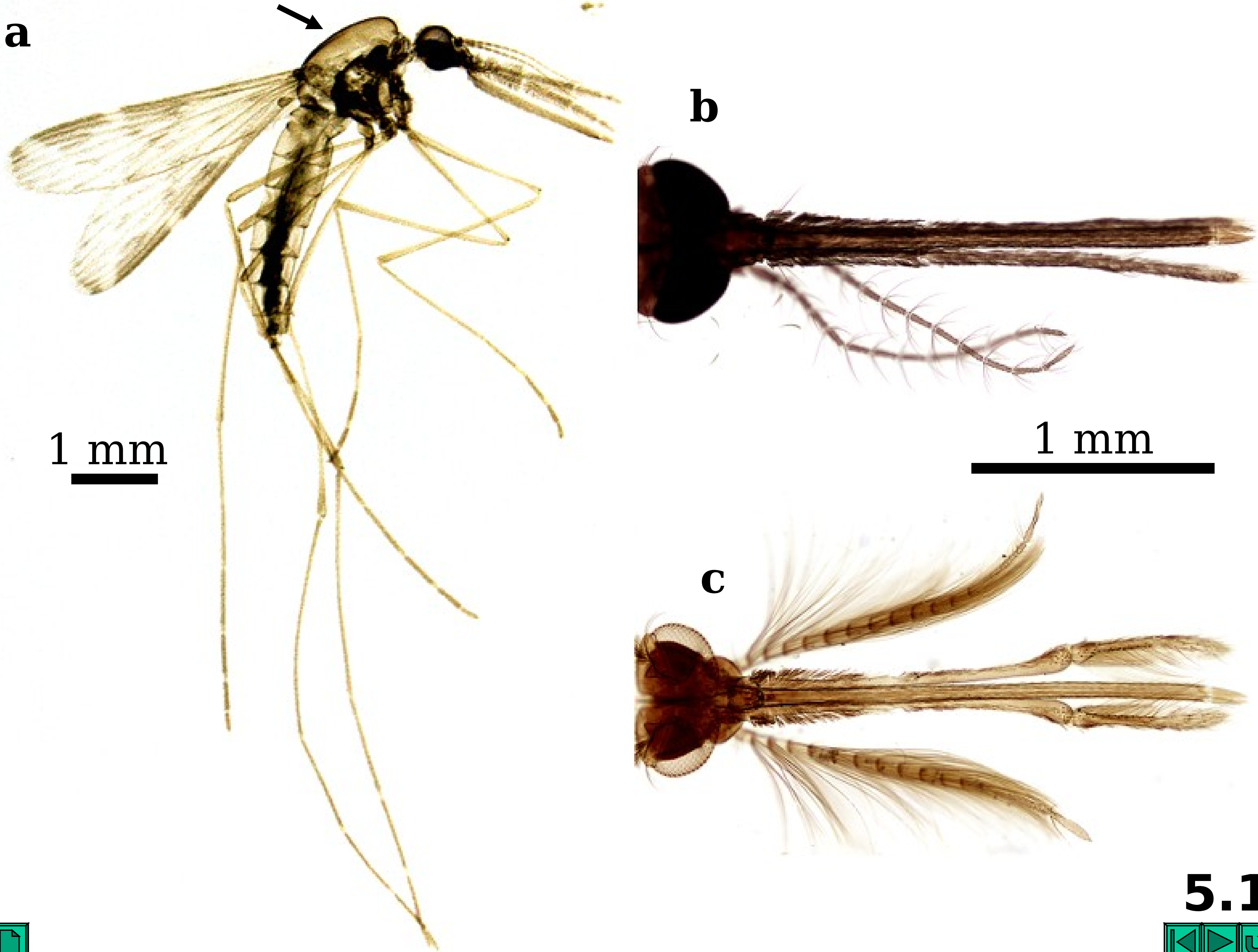
differentiation, ▯ cell division

intracellular packets of **SPORES**

released in feces or decaying host

5. Blood Apicomplexans

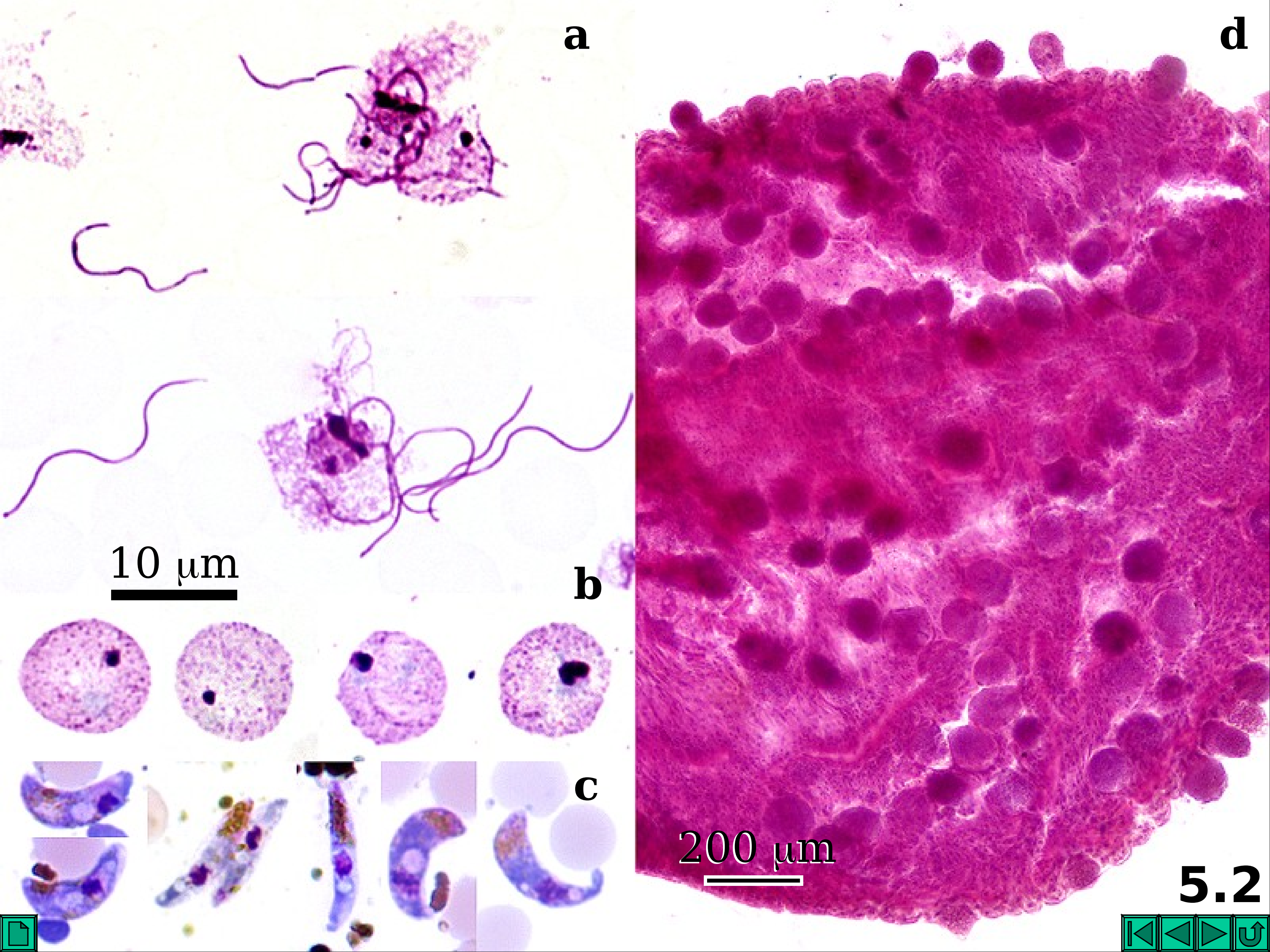
- *Anopheles* sp. mosquito
- Mosquito stages of *Plasmodium* spp.
- Sporozoites of *Plasmodium vivax*
- Exoerythrocytic schizont of *Plasmodium* sp.
- Trophozoites of *Plasmodium vivax*
- Erythrocytic schizonts of *Plasmodium vivax*
- Young trophozoites of *Plasmodium falciparum*
- Erythrocytic schizonts of *Plasmodium falciparum*
- Gametocytes of *Plasmodium falciparum*
- Cerebral malaria
- Trophozoites of *Plasmodium malariae*
- Erythrocytic schizonts of *Plasmodium malariae*
- Trophozoites of *Plasmodium ovale*
- Erythrocytic schizonts of *Plasmodium ovale*
- Gametocytes of *Plasmodium vivax, P. malariae, & P. ovale*
- Trophozoites of *Babesia bigemina & B. canis*



5.1

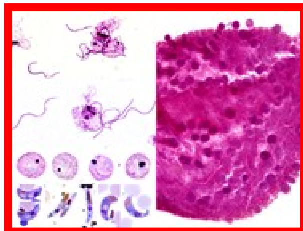
5.1 *Anopheles* sp. mosquito. **a.** Female. Note the long, spindly legs and relatively flat scutum (arrow), both characteristics of this genus. **b.** Mouthparts of female. **c.** Mouthparts of male. *Plasmodium* spp. infections are transmitted to humans by the bite of the female *Anopheles* mosquito. Males are physiologically capable of supporting parasite development, but since they do not feed on blood, they cannot transmit infection. Males are easily recognized by the plumose hairs on their antennae. This genus of mosquito can be identified by its palps, which are almost as long as the proboscis, and the 45-degree angle at which it sits when resting or feeding.

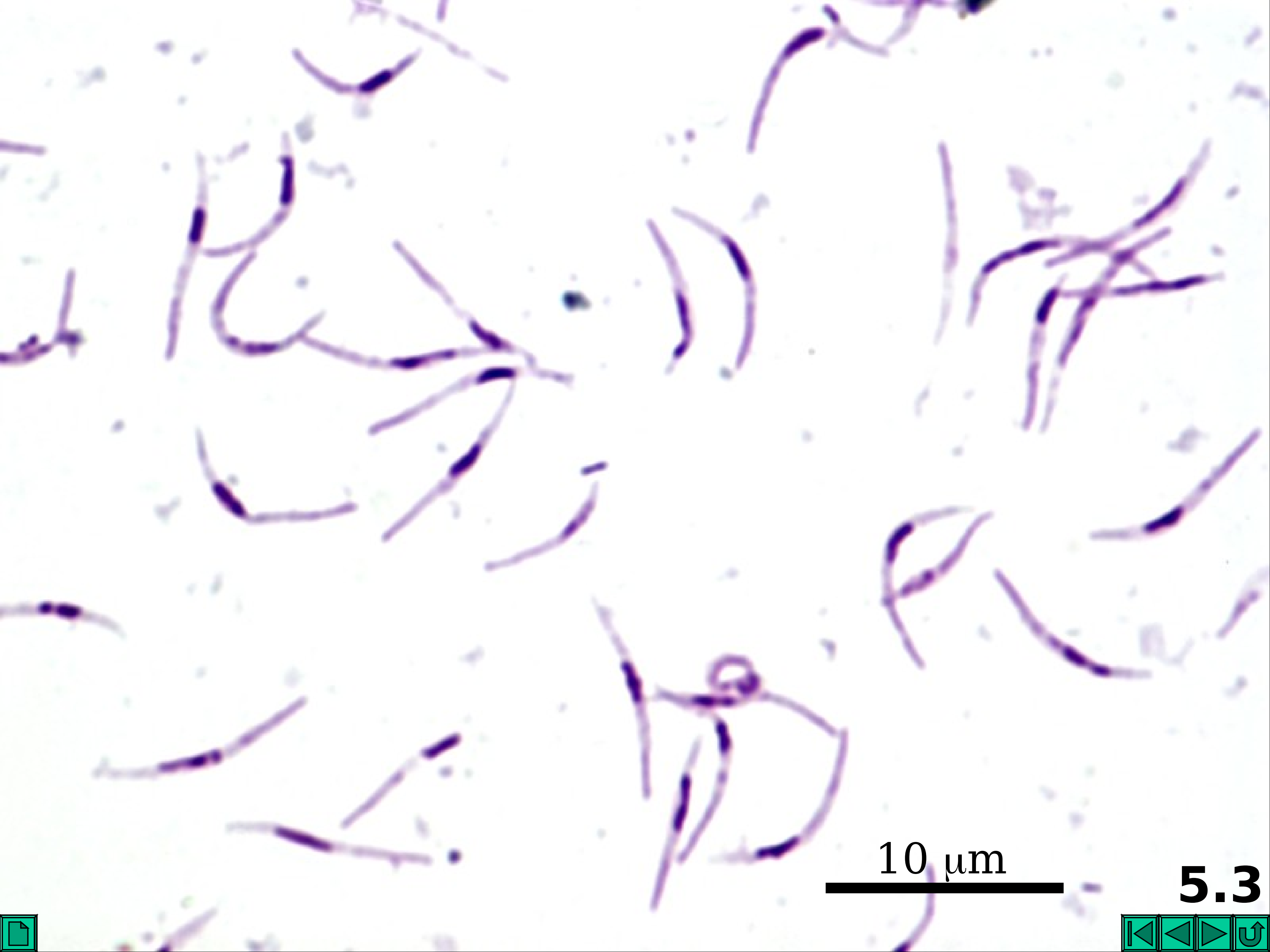
- back to mosquito stages of *Plasmodium*
- back to sporozoites of *Plasmodium*
- back to exoerythrocytic schizonts of *Plasmodium*


a
10 µm
b
c
d
200 µm

5.2 Stages of *Plasmodium* spp. occurring in the female *Anopheles* mosquito. Gametocytes taken up in a blood meal develop into gametes in the midgut, fertilization occurs, and the zygote (ookinete) penetrates the midgut wall to develop into an oocyst, which produces sporozoites. The sporozoites then migrate to the salivary gland. **a.** Formation of microgametes by the process of exflagellation. **b.** Macrogametes. **c.** Ookinetes. **d.** Oocysts on the surface of the midgut.

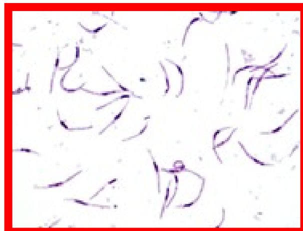
- back to sporozoites of *Plasmodium vivax*
- back to gametocyte of *Plasmodium falciparum*

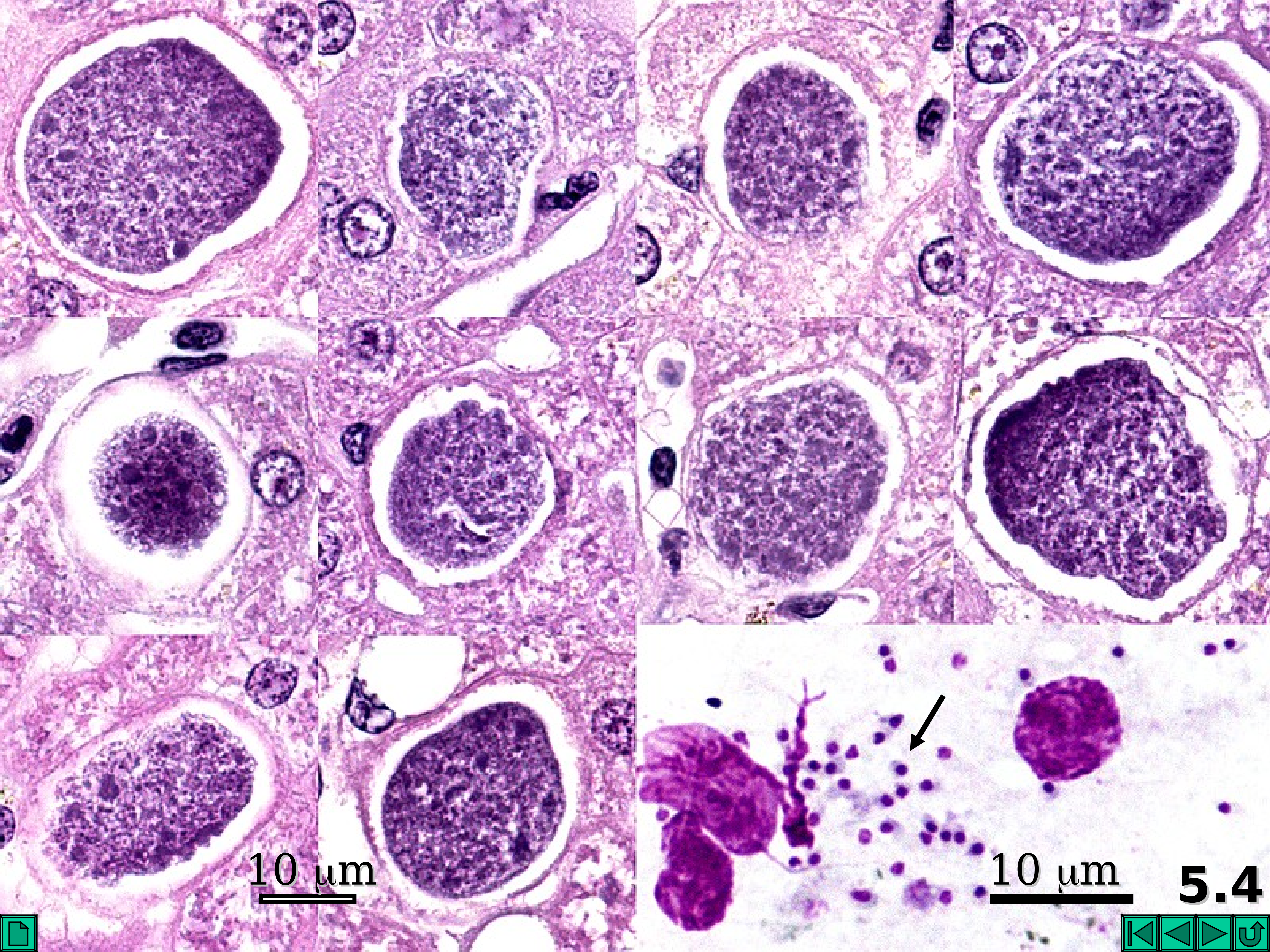



10 µm

5.3 Sporozoites of *Plasmodium vivax* in a squash of an oocyst from an infected *Anopheles* mosquito. Sporozoites develop in oocysts on the wall of the midgut, and then migrate in the hemolymph to the salivary glands. Several thousand may be injected into the host by one mosquito during feeding. Upon reaching the liver, each will penetrate into an hepatocyte and develop into an exoerythrocytic schizont.

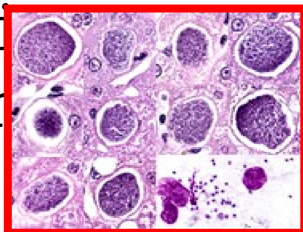
- back to gametocytes of *Plasmodium falciparum*

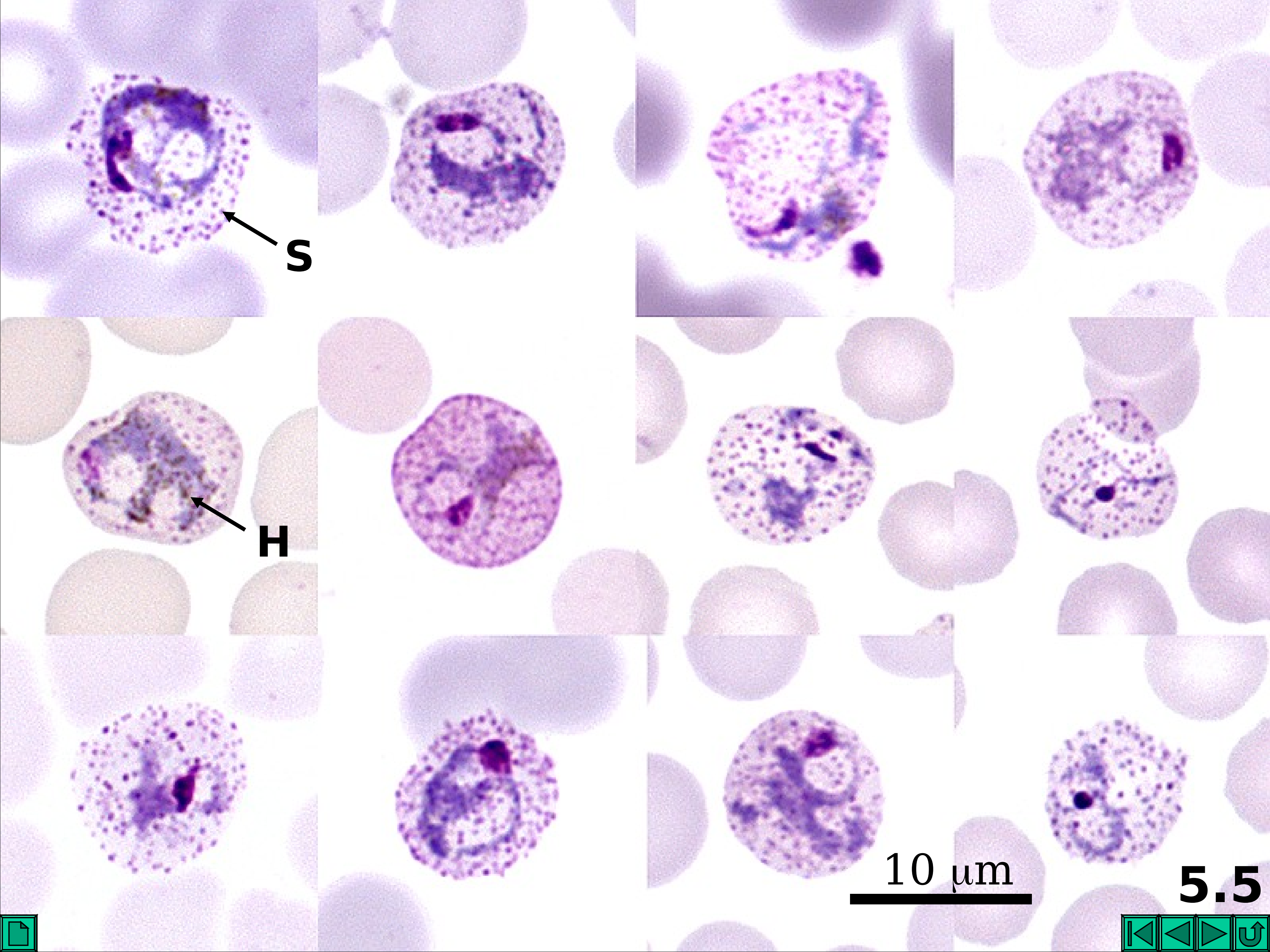



10 µm
10 µm

5.4 Exoerythrocytic schizonts of *Plasmodium* sp. in liver cells. Once introduced into the bloodstream by the bite of an *Anopheles* mosquito, sporozoites of *Plasmodium* penetrate hepatocytes. Each undergoes schizogony (merogony), to produce an exoerythrocytic (EE) schizont, which is a single multinucleate cell. Cytokinesis occurs, and thousands of merozoites burst from the hepatocyte within 1-2 weeks post infection, depending upon the species (e.g., 40,000 merozoites in 5-7 days in the case of *P. falciparum*). Bottom right frame shows merozoites (arrow) in a liver squash preparation. These merozoites then infect erythrocytes. During infections with *P. vivax* and *P. ovale*, some EE schizonts develop into dormant hypnozoites, and upon becoming acti
may cause a relapse of the disease years after
supposed cure.

- back to *Babesia* spp.

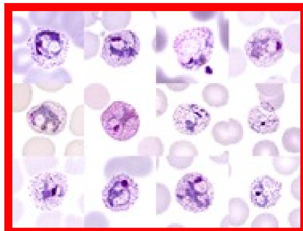


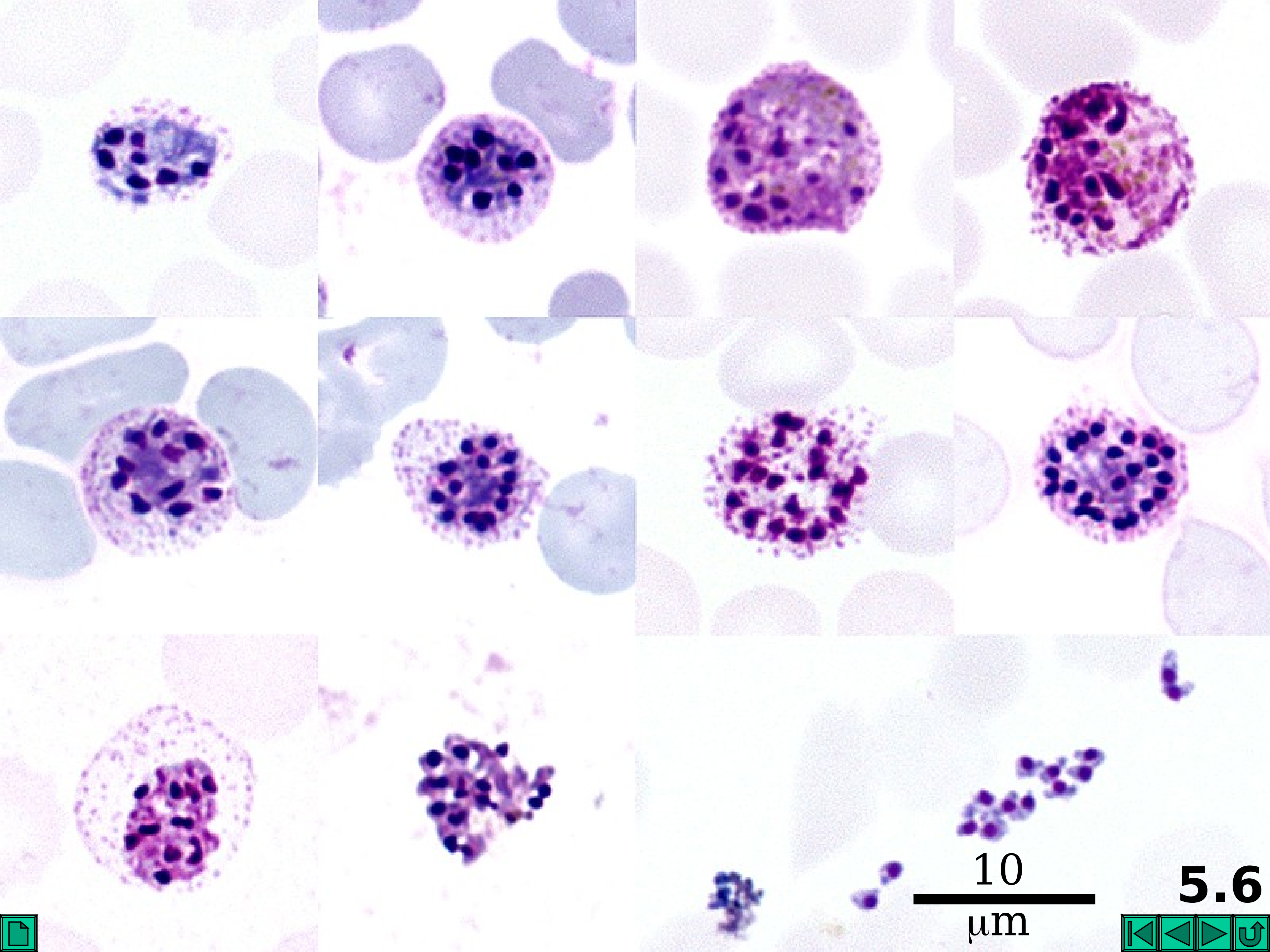


5.5

5.5 Trophozoites of *Plasmodium vivax*. These can be identified as *P. vivax* by the following features: enlarged, decolorized infected erythrocytes; prominent Schüffner's dots (S); and the ameboid shape of the trophozoite. Hemozoin granules (H) may be relatively difficult to identify in this species. Malaria caused by *P. vivax* usually is not life-threatening.

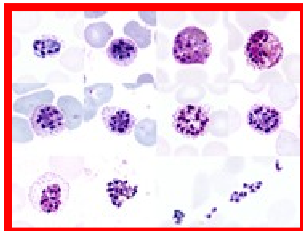
- back to trophozoites of *Plasmodium malariae*
- back to trophozoites of *Plasmodium ovale*

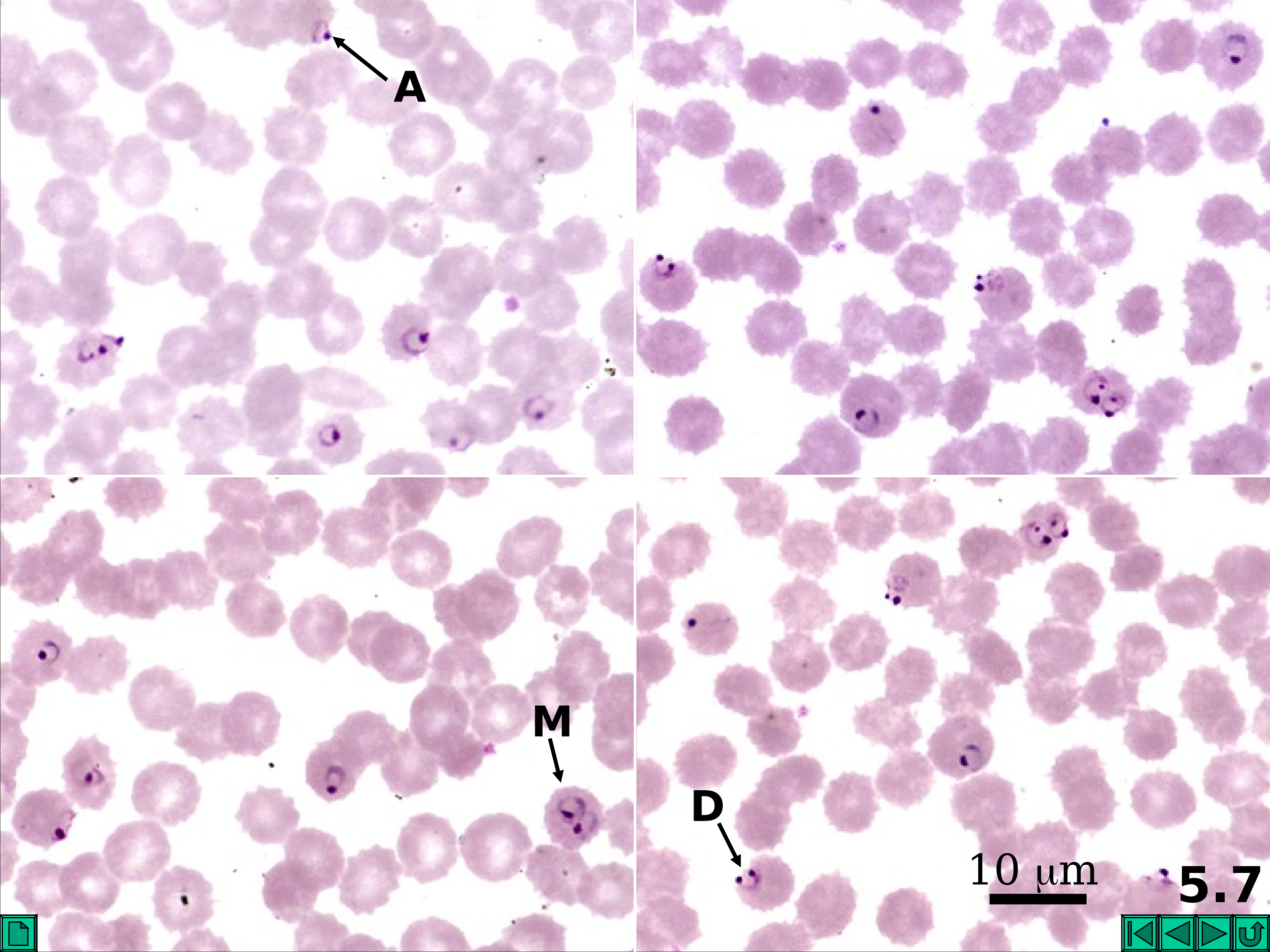




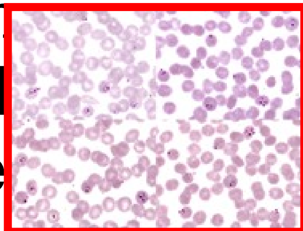
5.6

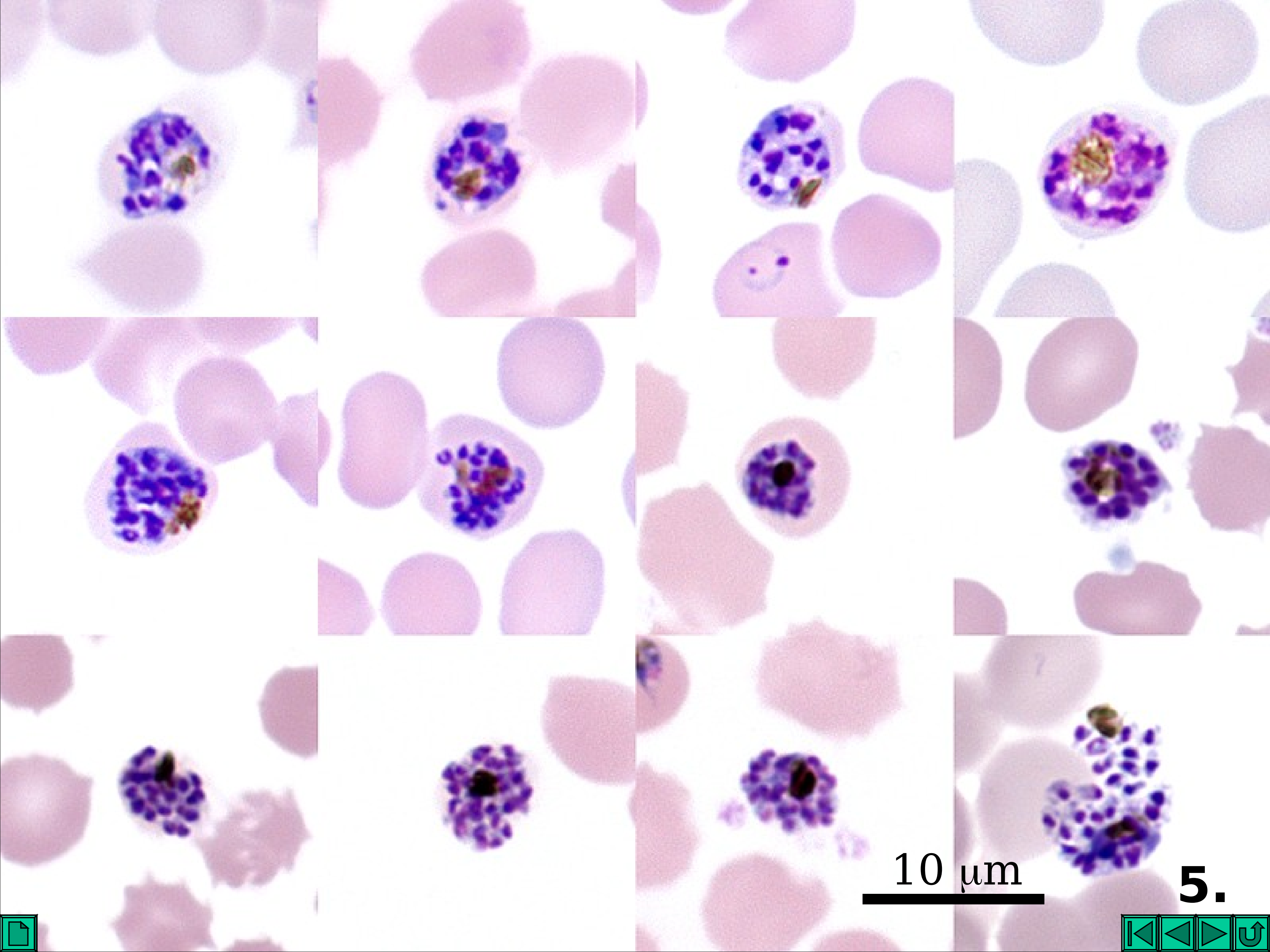
5.6 Erythrocytic schizonts of *Plasmodium vivax*. When merozoites invade host erythrocytes, most undergo schizogony to produce 12 to 24 merozoites (average of 16) within approximately 48 hours. These burst out of the cell and immediately infect new cells. Because the infection becomes synchronous in the host, large numbers of infected erythrocytes burst more or less simultaneously, causing a rapid rise in body temperature at 48-hour intervals.




A
M
D
10 μm

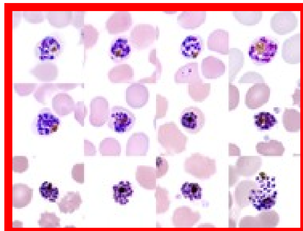
5.7 Young signet ring stage trophozoites of *Plasmodium falciparum*. This organism kills more people annually than all other parasites combined. Because of its pathogenicity, a failure to recognize *P. falciparum* infection in smears like the ones shown here may have fatal consequences. Diagnostic features are: high parasitemia; presence of only signet ring trophozoites; appliqué forms (A), double chromatin dots (D), and multiple infections (M) in some cells; and absence of Schüffner's dots. Soon after this stage, infected cells disappear from the circulation by adhering to endothelial cells of blood vessels in the tissues, making diagnosis difficult and potentially leading to cerebral malaria. Schizogony results in new infected erythrocytes, which reappear in the peripheral blood at 48-h intervals. Some individuals who are apparentl "cured" of infection may develop symptoms ye

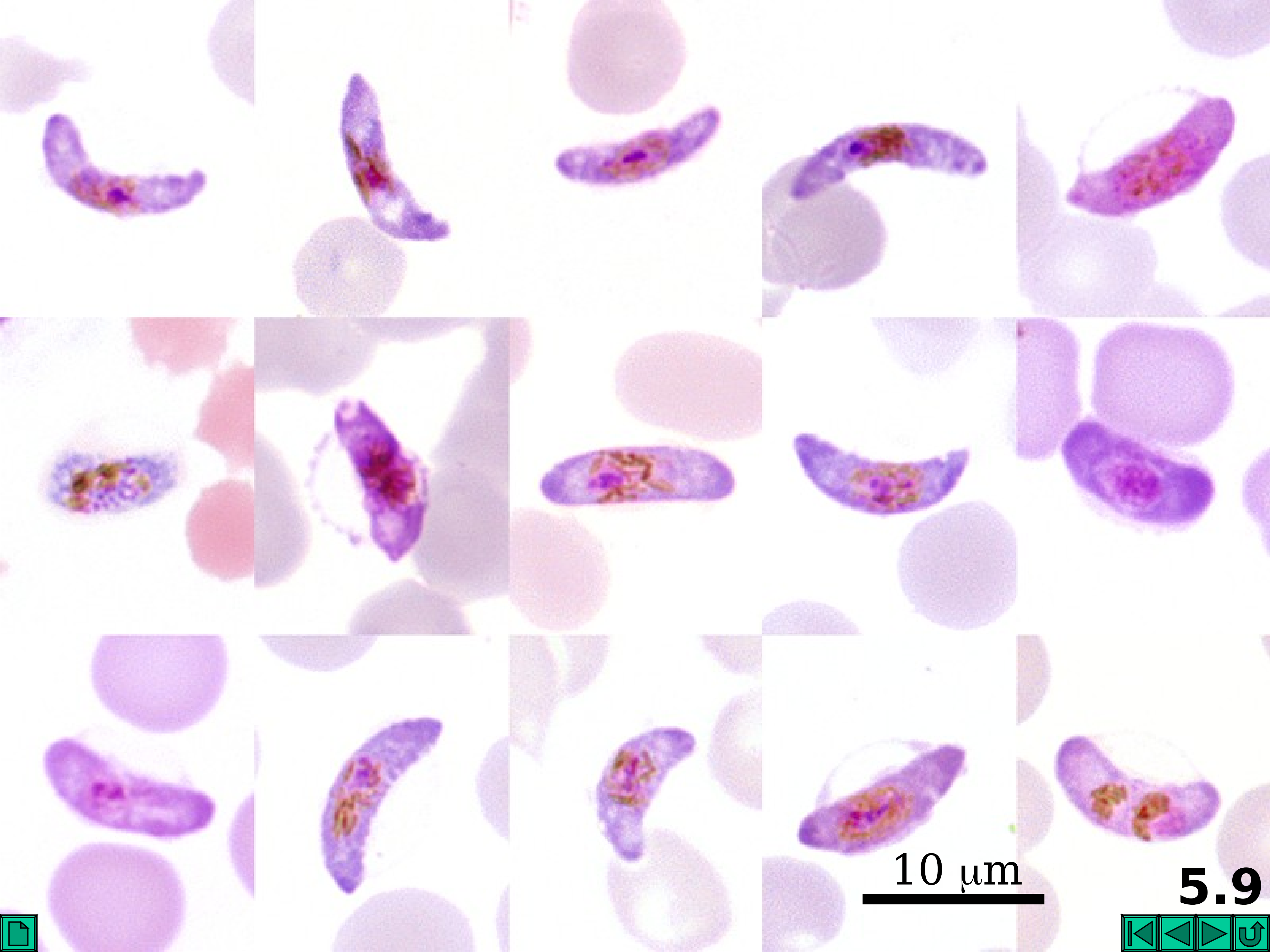




5.

5.8 Erythrocytic schizonts of *Plasmodium falciparum*. This stage usually is not observed in peripheral blood, except in very heavy infections. Each schizont produces from 6 to 32 merozoites, with an average of 20 to 24, every 48 hours. Brown hemozoin pigment is typically clumped in the center of the infected RBC. Note that the merozoites are very small, and that the schizont usually does not fill up the RBC.

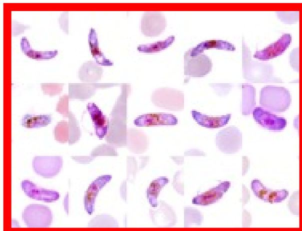


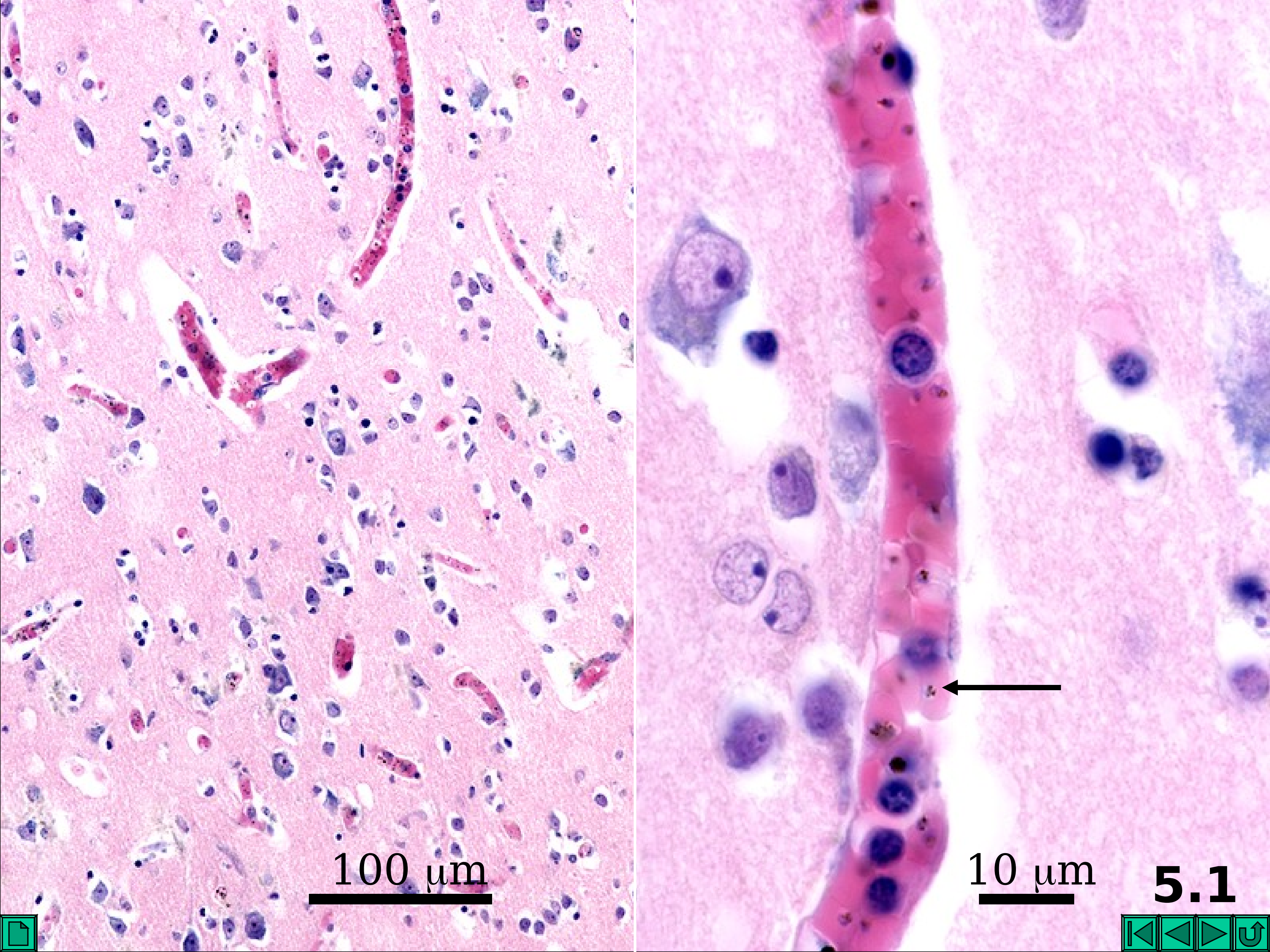


5.9

5.9 Gametocytes of *Plasmodium falciparum*. Some merozoites penetrate erythrocytes and differentiate into gametocytes instead of undergoing schizogony. Although the gametocytes of all four human-infecting species can be distinguished, those of *P. falciparum* have a unique appearance, and therefore are valuable in diagnosis. Macrogametocytes of this species are elongate, and have a nucleus less than one-half the length of the cell. Microgametocytes may be shorter and more blunt-ended, have a lighter blue cytoplasm, and have a nucleus that is greater than one-half the length of the cell. Gametocytes do not produce gametes until they reach the midgut of a mosquito. The gametes fuse to produce a zygote that elongates into an ookinete. The ookinete penetrates the midgut wall and develops into oocyst, in which sporozoites are produced.

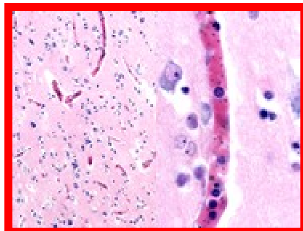
- back to gametocytes of *Plasmodium vivax*, *P. malariae*, and *P. ovale*

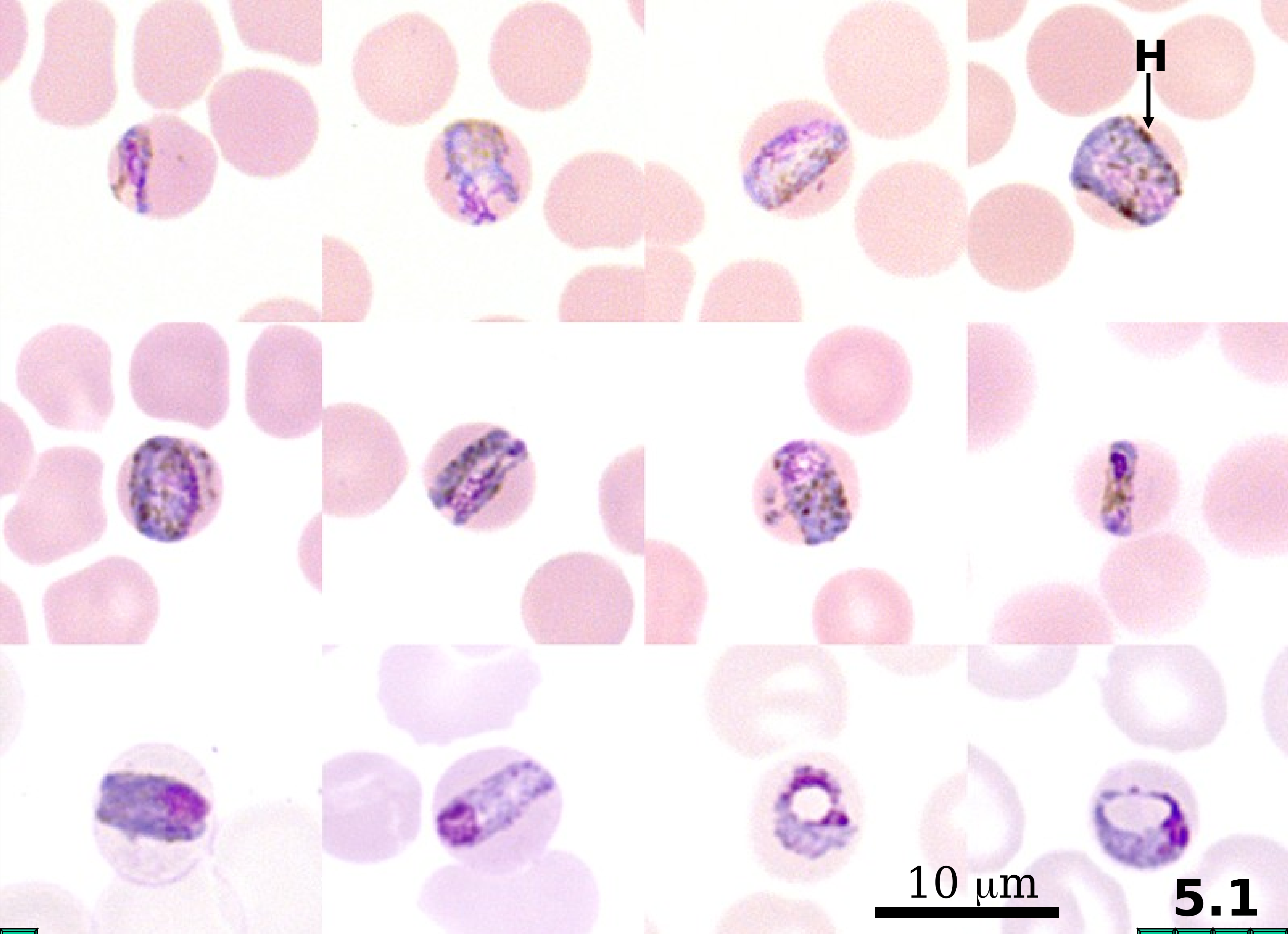



100 μm
10 μm

5.10 Histological section of brain from a case of cerebral malaria. In *Plasmodium falciparum* infections, the surfaces of infected red blood cells express parasite proteins that cause them to adhere to the endothelial lining of blood vessels in the organs. Note the congested blood vessels in the low magnification view on the left, which at higher magnification on the right are seen to be clogged with infected red blood cells, visible by their black deposits of hemozoin pigment in the parasite cytoplasm (arrow). Cerebral malaria can be rapidly lethal, especially in small children and nonimmune adults, and is a major reason that *P. falciparum* is one of the greatest killers of humans.

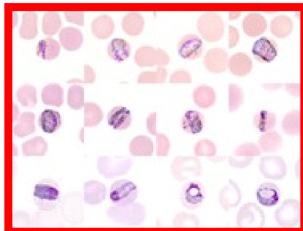
- back to young trophozoites of *Plasmodium falciparum*

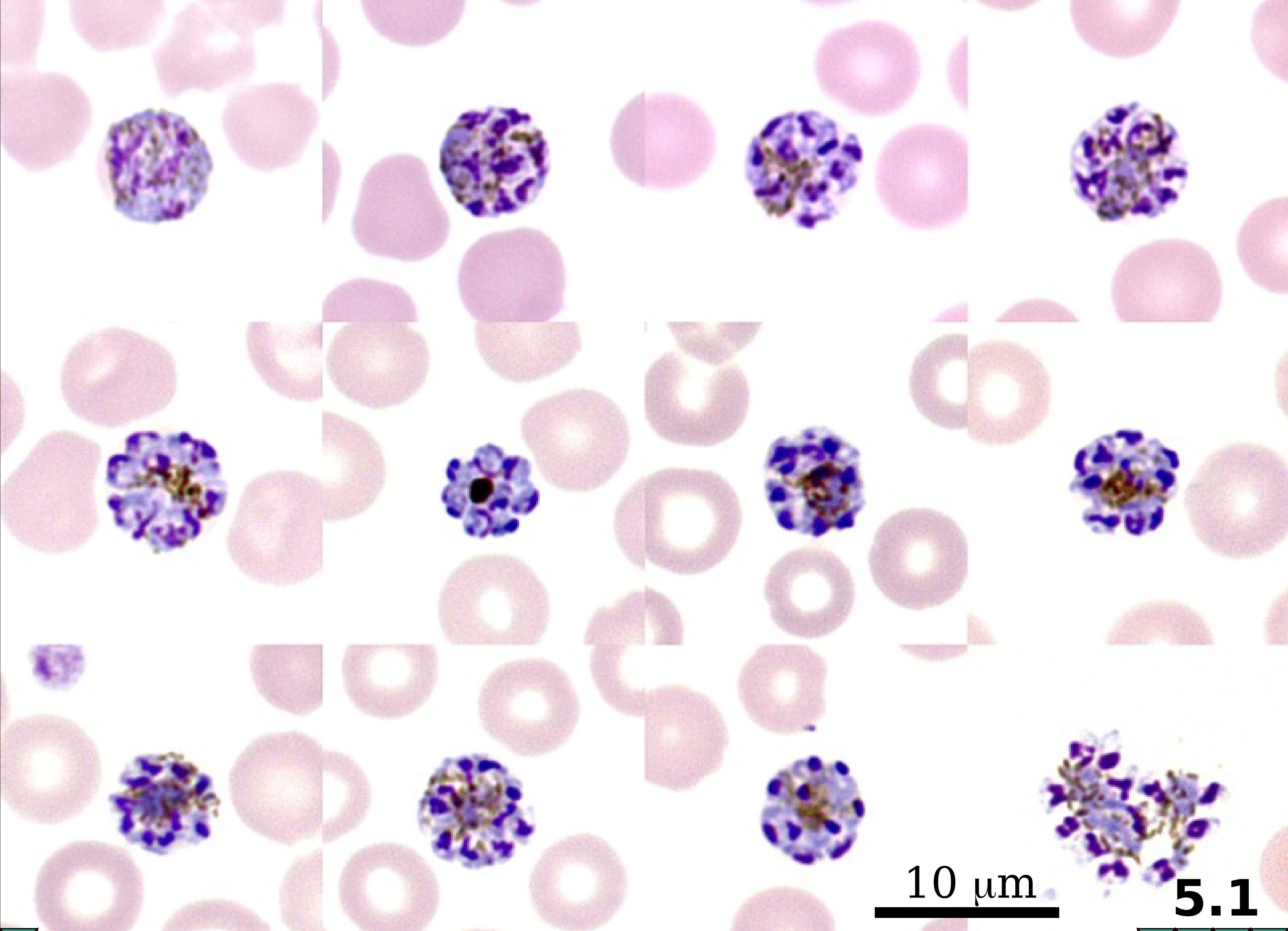




5.1

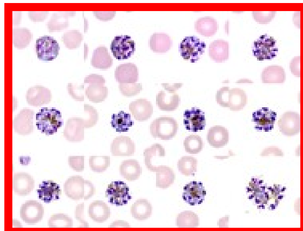
5.11 Trophozoites of *Plasmodium malariae.* Occasionally trophozoites form a band shape, stretching across the red blood cell, as shown in these photographs. So-called basket forms may also be observed, in which the young trophozoite resembles a handbasket (bottom right two frames). The cytoplasm of the parasite stains more darkly than in *P. vivax,* and there are no Schüffner's dots. Hemozoin granules (H) are much more conspicuous in this species than in the other three. Unlike the case with *P. vivax,* infected erythrocytes are not enlarged.

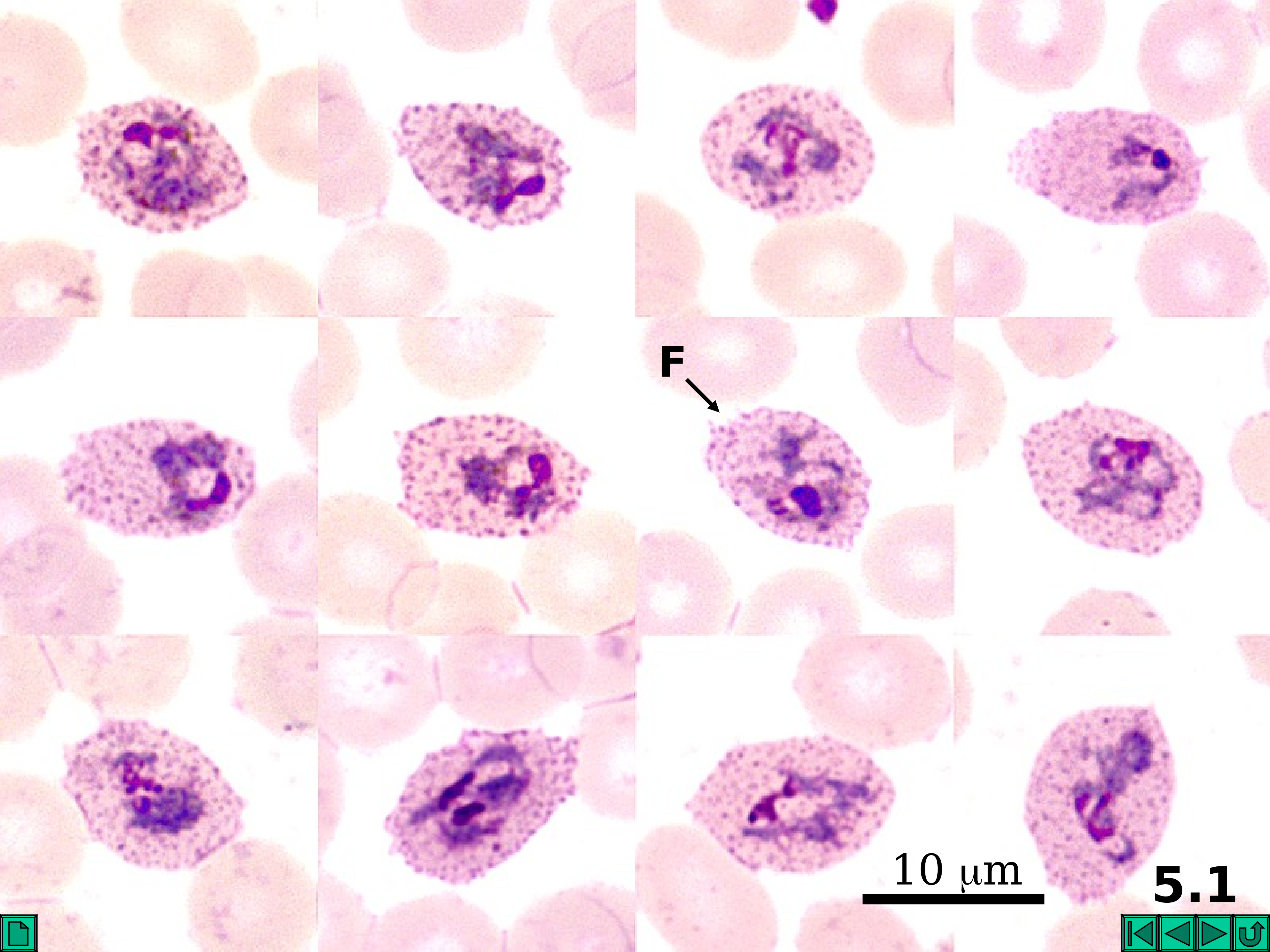




5.1

5.12 Erythrocytic schizonts of *Plasmodium malariae*. From 6 to 12 merozoites (average of 8) form in each infected cell at 72-hour intervals. The merozoites are often, but not always, arranged in a rosette around the periphery, with the hemozoin granules at the center.

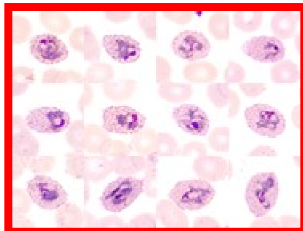


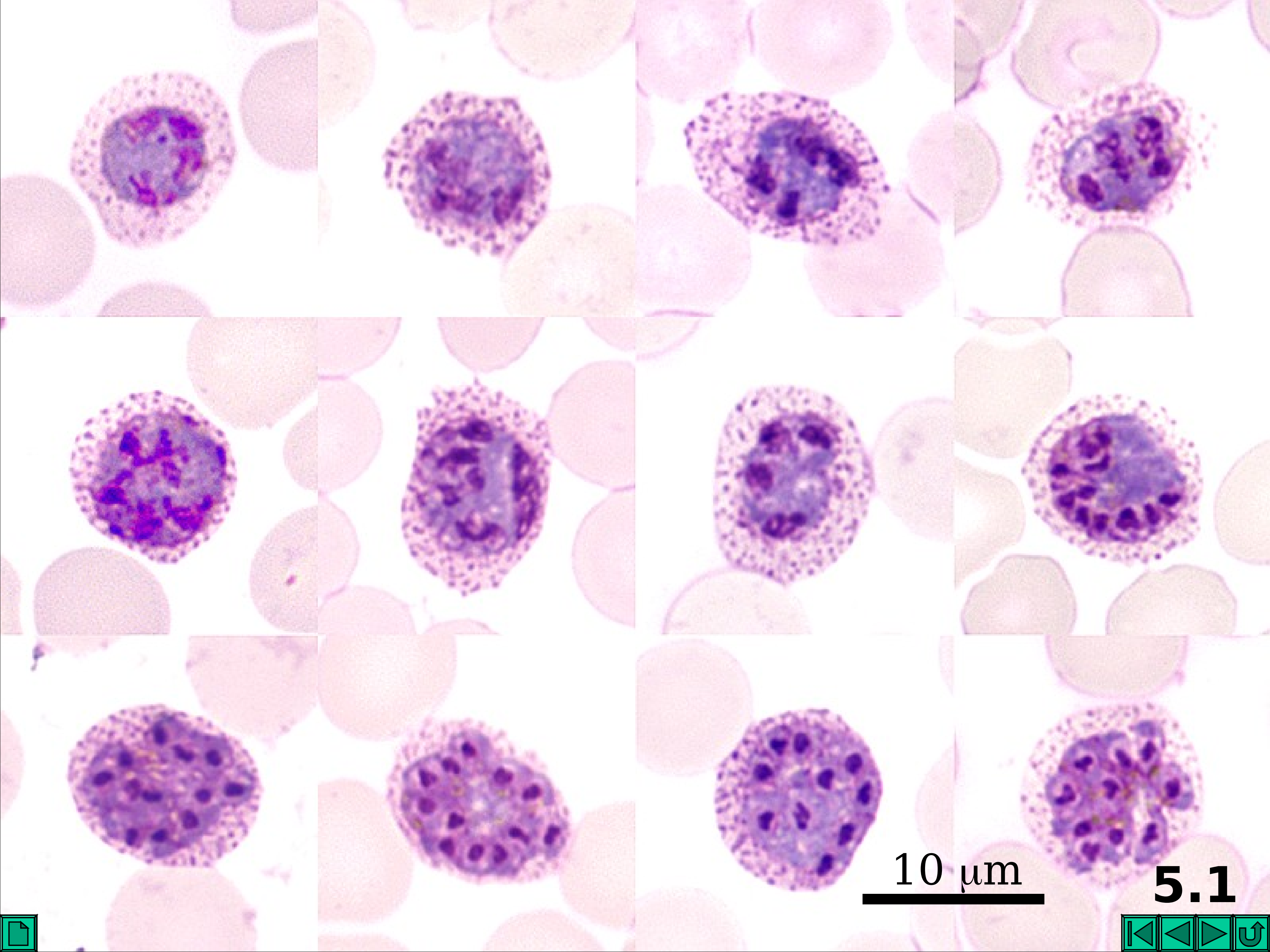


5.1

5.13 Growing trophozoites of *Plasmodium ovale.* This species has the lowest prevalence among malarial parasites, occurring mainly in tropical Africa. Although sometimes difficult to distinguish from *P. vivax,* from 20-60% of infected cells show oval distortion (versus around 5% in *P. vivax*), as depicted in this plate. Schüffner’s dots and hemozoin granules are prominent, as is the large chromatin mass. Also, infected cells are enlarged (although usually not as enlarged as with *P. vivax*), and some of the infected cells have fimbriated (fringed) edges (F).

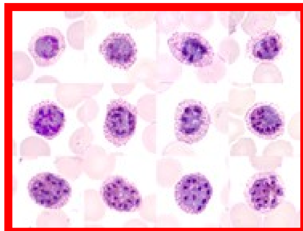
- back to erythrocytic schizont of *Plasmodium ovale*

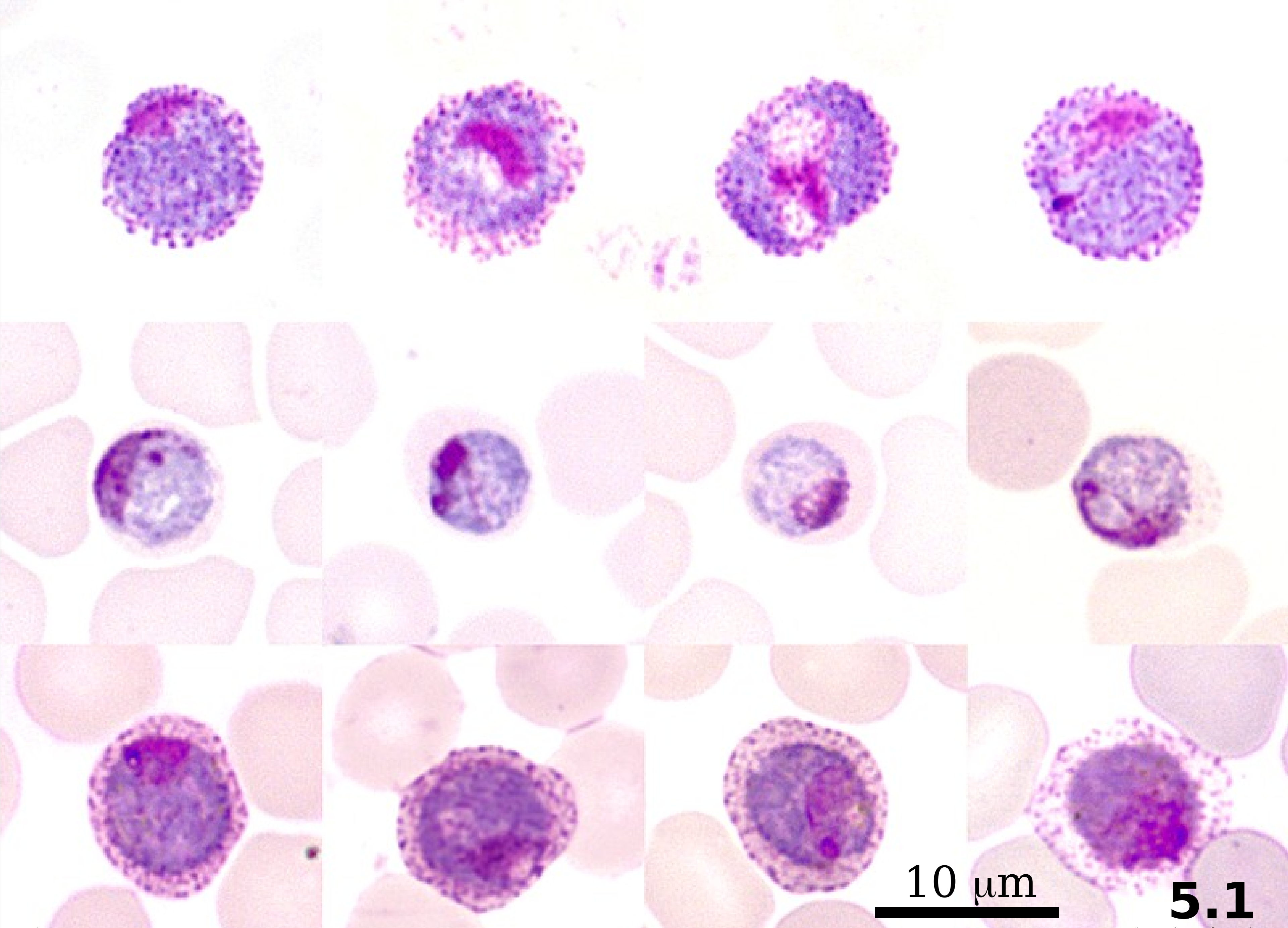




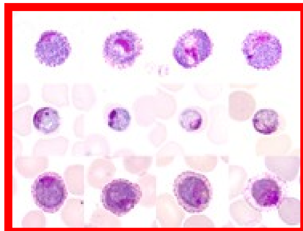
5.1

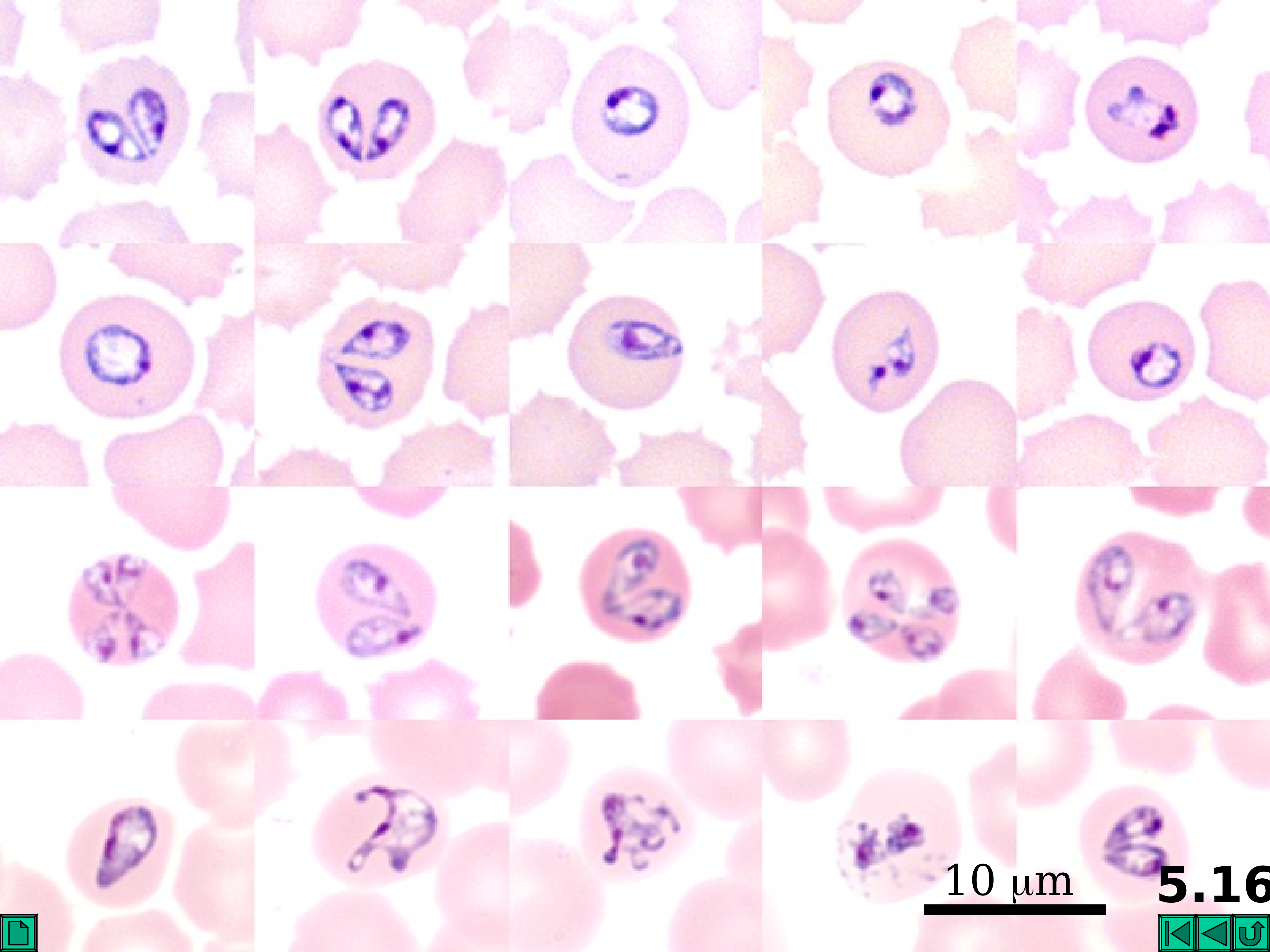
5.14 Erythrocytic schizonts of *Plasmodium ovale*. This stage shares many diagnostic features with the trophozoite stage: enlarged, ovally-distorted host cells, and prominent Schüffner’s dots. From 6 to 14 merozoites (average = 8) are produced by each schizont in 48 hr.




10 µm

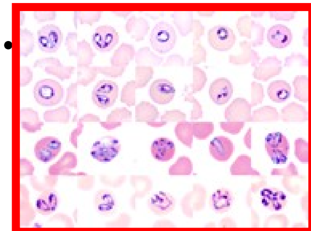
5.15 Gametocytes of *Plasmodium vivax* (first row), *P. malariae* (second row), and *P. ovale* (third row). Unlike the gametocytes of *P. falciparum*, these stages are not very useful for distinguishing among species. Macrogametocytes tend to possess more compact chromatin (e.g., top left frame), whereas the chromatin of microgametocytes is more dispersed (e.g., top right and bottom right frames).



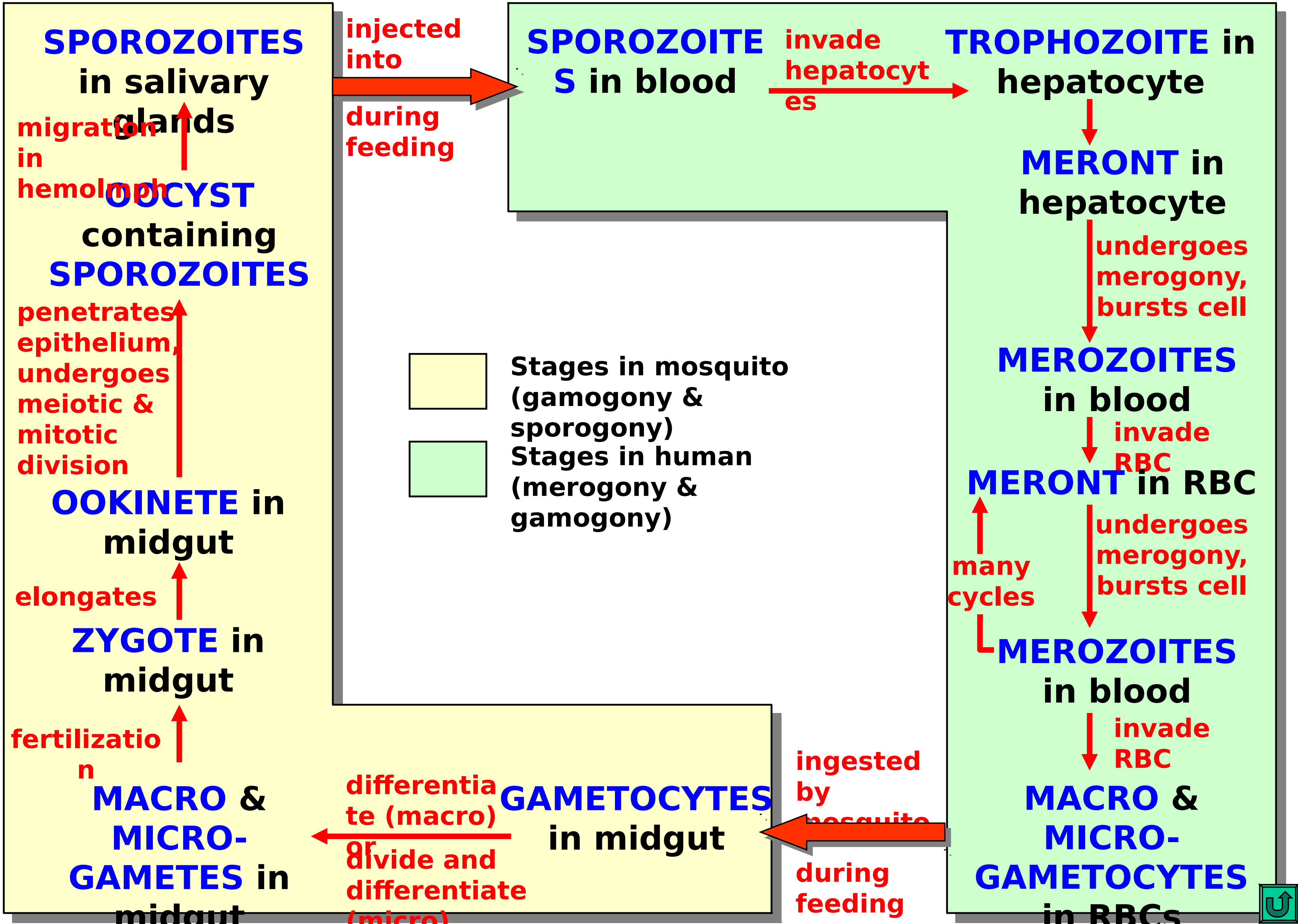


5.16

5.16 Trophozoites of *Babesia bigemina* from cow blood (first two rows) and *B. canis* from dog blood (second two rows) . Trophozoites are pear shaped and often occur in pairs or fours, joined at the tip, a result of binary schizogony. A related species in rodent reservoirs, *B. microti,* has caused numerous human infections on the northeast coast of the U.S. The resulting malaria-like disease can be treated with anti-trypanosome drugs, but usually self cures without complication except in splenectomized patients, for whom it may be fatal. There is no exoerythrocytic schizogony in the life cycle, and the vector is a tick. In some species of *Babesia,* transovarial transmission may occur from one tick generation to the next, allowing the parasite to persist in ticks that feed on only a single host. Patient history (no travel to a malarious area) the absence of hemozoin may allow one to



Life cycle of *Plasmodium* spp.



SPOROZOITES in salivary glands

migration in hemolymph

OOCYST containing **SPOROZOITES**

penetrates epithelium, undergoes meiotic & mitotic division

OOKINETE in midgut

elongates

ZYGOTE in midgut

fertilization

MACRO & **MICRO-GAMETES** in midgut

injected into

during feeding

SPOROZOITES in blood

invade hepatocytes

TROPHOZOITE in hepatocyte

MERONT in hepatocyte

undergoes merogony, bursts cell

MEROZOITES in blood

invade RBC

MERONT in RBC

undergoes merogony, bursts cell

many cycles

MEROZOITES in blood

invade RBC

MACRO & **MICRO-GAMETOCYTES** in RBCs

ingested by mosquito

during feeding

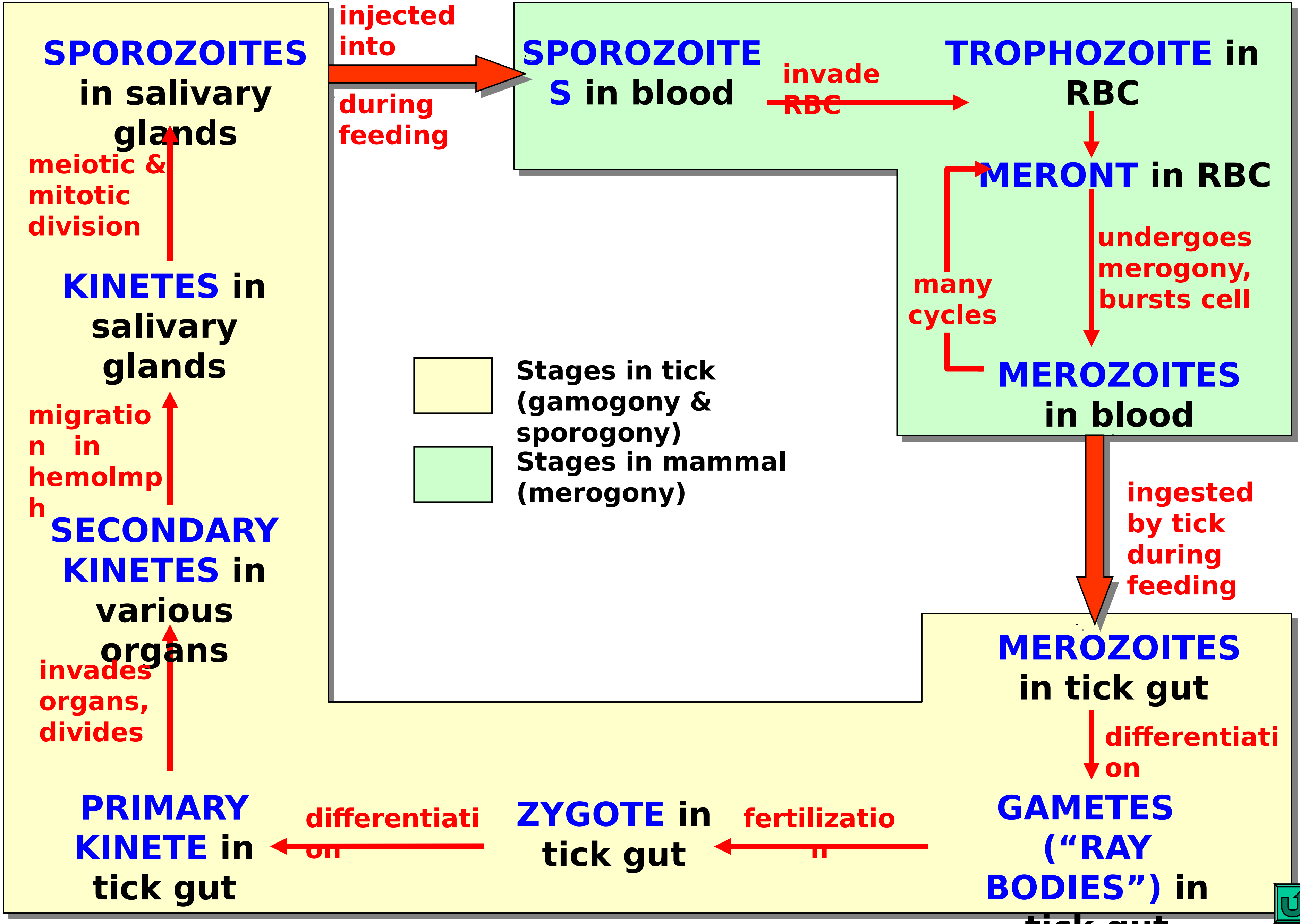
GAMETOCYTES in midgut

differentiate (macro) or divide and differentiate (micro)

🟨 Stages in mosquito (gamogony & sporogony)

🟩 Stages in human (merogony & gamogony)

Life cycle of *Babesia* spp.



SPOROZOITES in salivary glands

injected into during feeding

SPOROZOITES in blood

invade RBC

TROPHOZOITE in RBC

MERONT in RBC

undergoes merogony, bursts cell

many cycles

MEROZOITES in blood

ingested by tick during feeding

MEROZOITES in tick gut

differentiation

GAMETES (“RAY BODIES”) in tick gut

fertilization

ZYGOTE in tick gut

differentiation

PRIMARY KINETE in tick gut

invades organs, divides

SECONDARY KINETES in various organs

migration in hemolmph

KINETES in salivary glands

meiotic & mitotic division

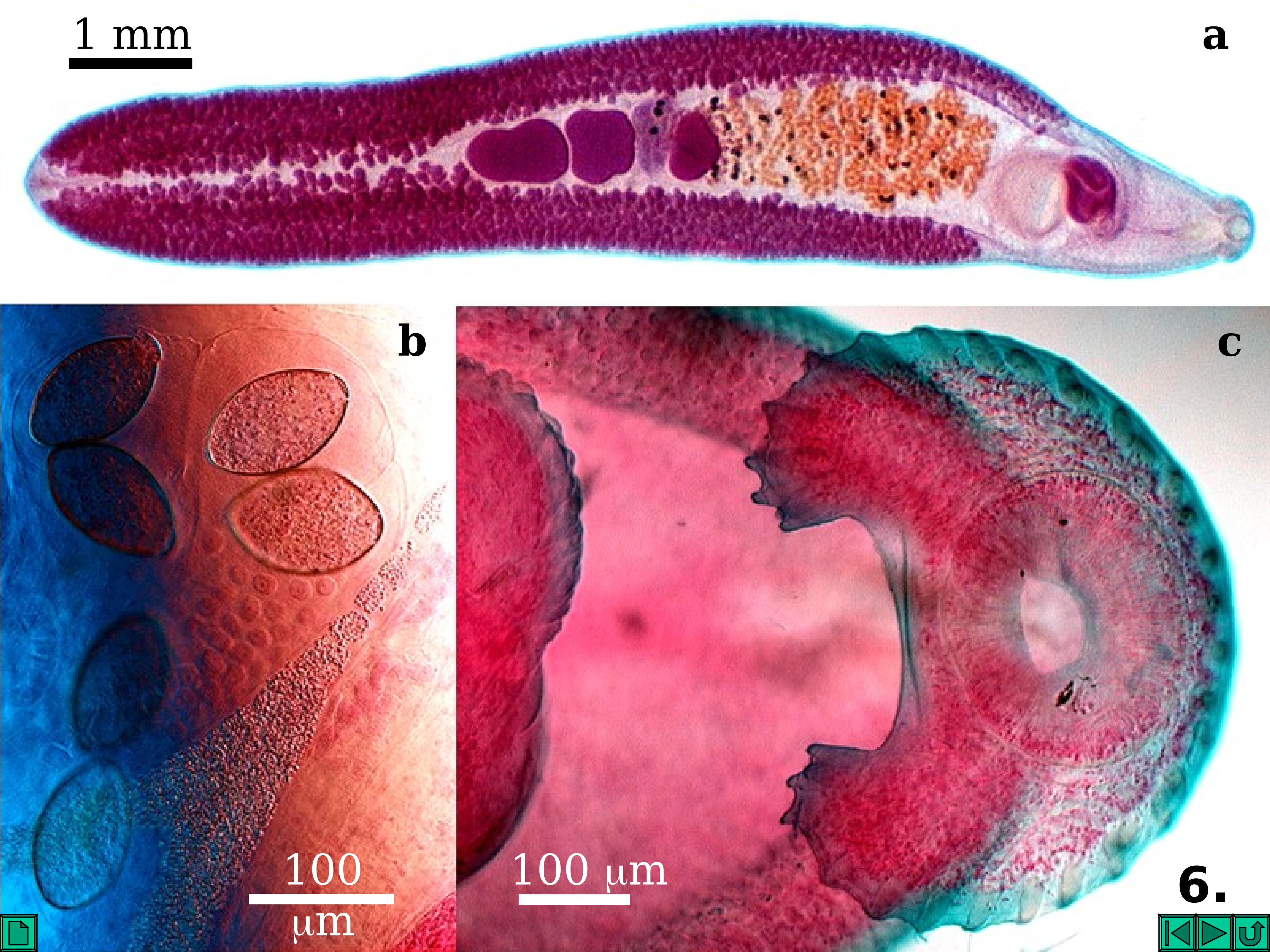
🟨 Stages in tick (gamogony & sporogony)

🟩 Stages in mammal (merogony)

6. Trematodes (Flukes)

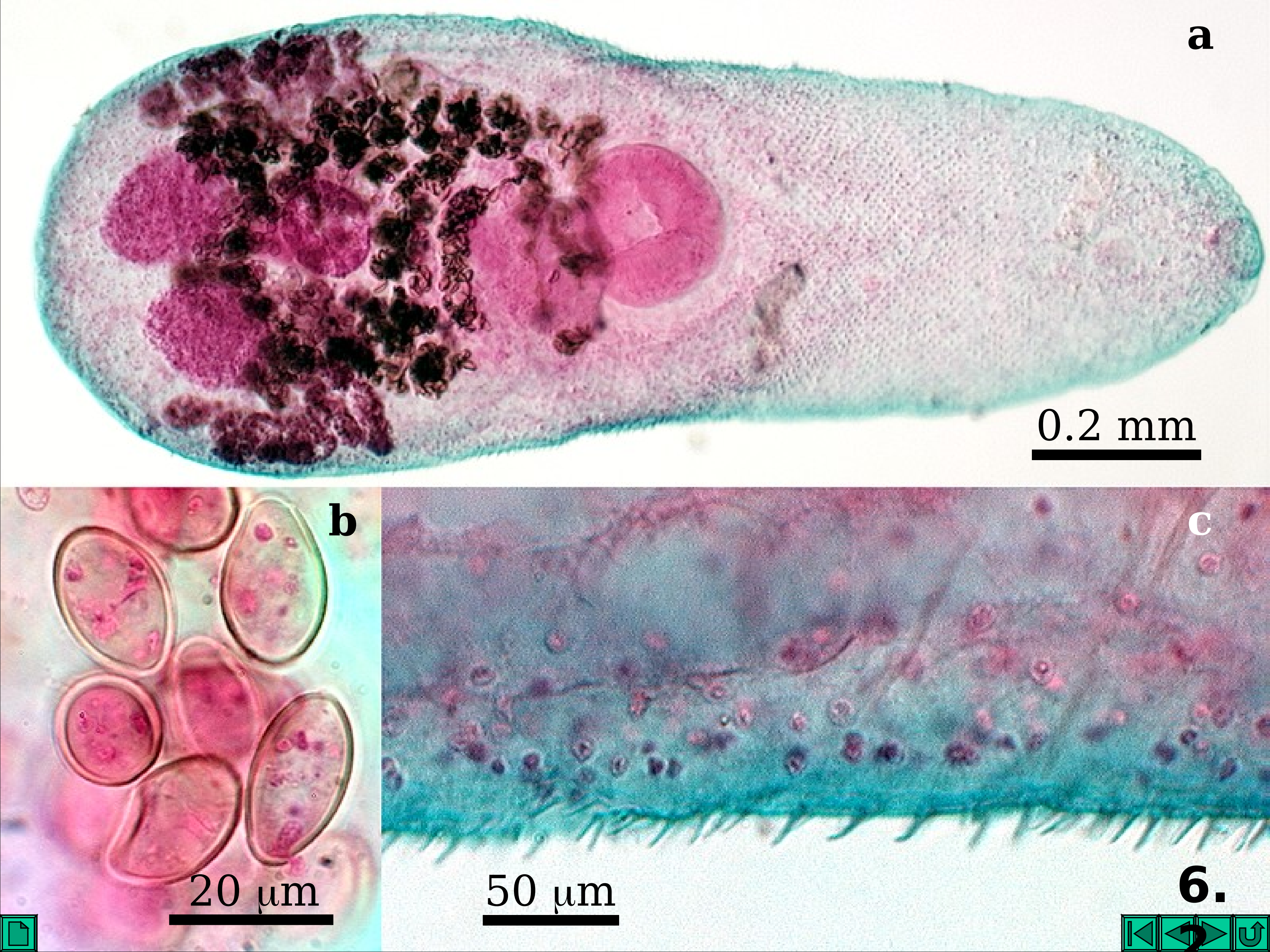
- *Echinostoma revolutum*
- *Heterophyes heterophyes*
- *Fasciolopsis buski*
- *Fasciola hepatica*
- *Clonorchis sinensis*
- *Dicrocoelium dendriticum*
- *Paragonimus westermani*
- *Schistosoma mansoni*
- Eggs of *Clonorchis sinensis*
- Eggs of *Fasciola hepatica*
- Eggs of *Paragonimus westermani*
- Eggs of *Schistosoma haematobium*
- Eggs of *Schistosoma japonicum*
- Eggs of *Schistosoma mansoni*
- Eggs of *Echinostoma paraensei*
- Metacercariae
- Life cycle of *Schistosoma mansoni*
- Schistosome-transmitting snails
- *Phagicola nana* in intestine
- *Clonorchis sinensis* & *Fasciola hepatica* in bile duct
- *Paragonimus westermani* in lung
- *Schistosoma mansoni* eggs in liver
- *Schistosoma mansoni* eggs in intestine
- *Schistosoma haematobium* eggs in bladder

I T


1 mm
a
b
c
100 μm
100 μm

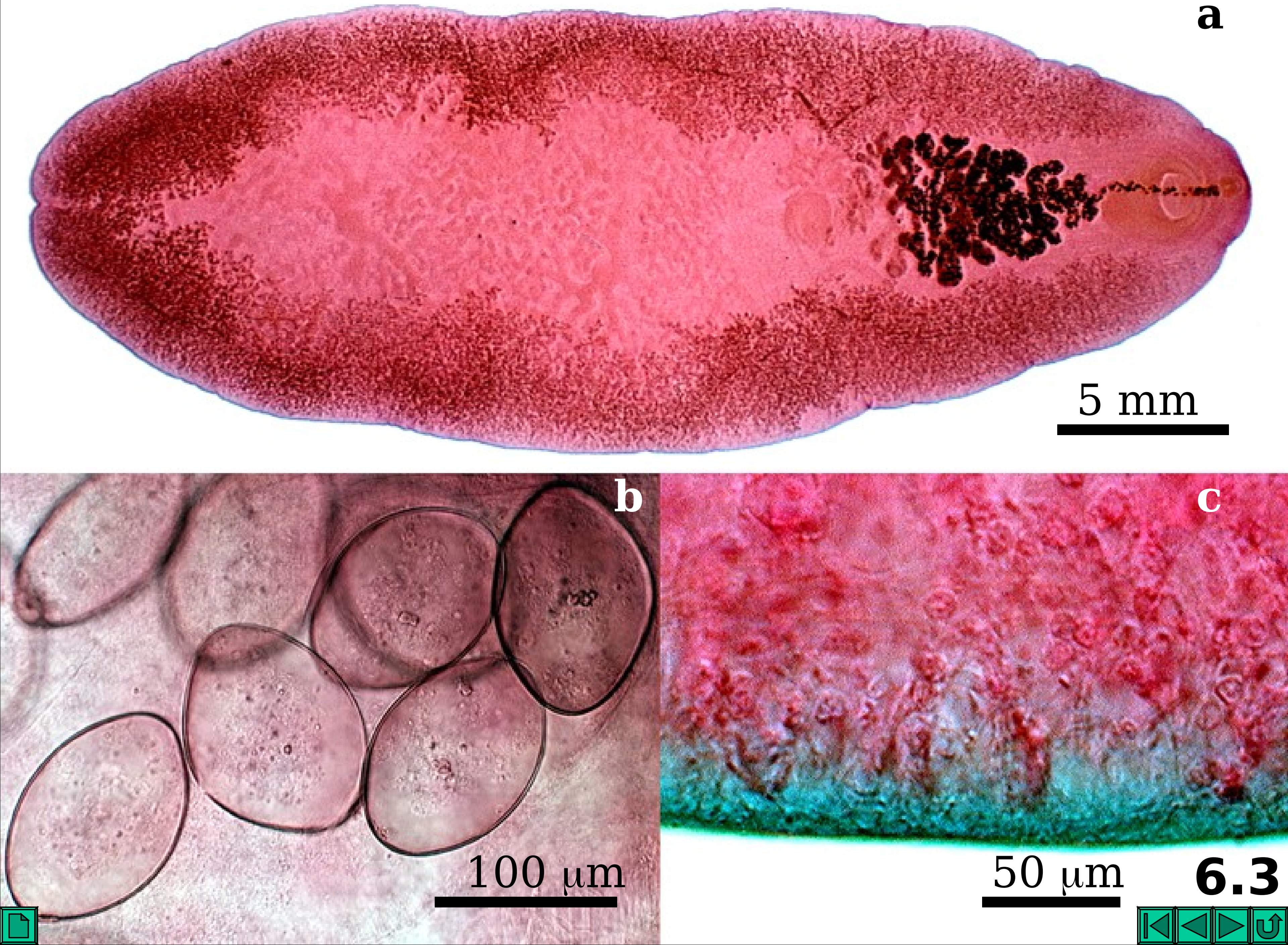
6.

6.1 *Echinostoma revolutum*. **a.** Adult worm. Echinostomes are intestinal parasites with a worldwide distribution. Infection results from ingesting metacercariae, usually in uncooked molluscs. Mammals and birds serve as reservoir hosts. Heavy infections may cause diarrhea. For a labeled photo of the adult, click here. **b.** Newly formed eggs in the uterus, which are passed out unembryonated in the feces of the definitive host. **c.** Collar of spines surrounding mouth, the feature that gives echinostomes their name.


a
0.2 mm
b
20 μm
c
50 μm

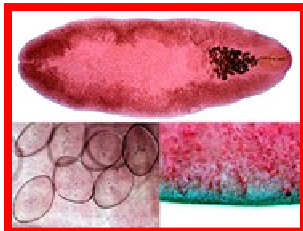
6.2

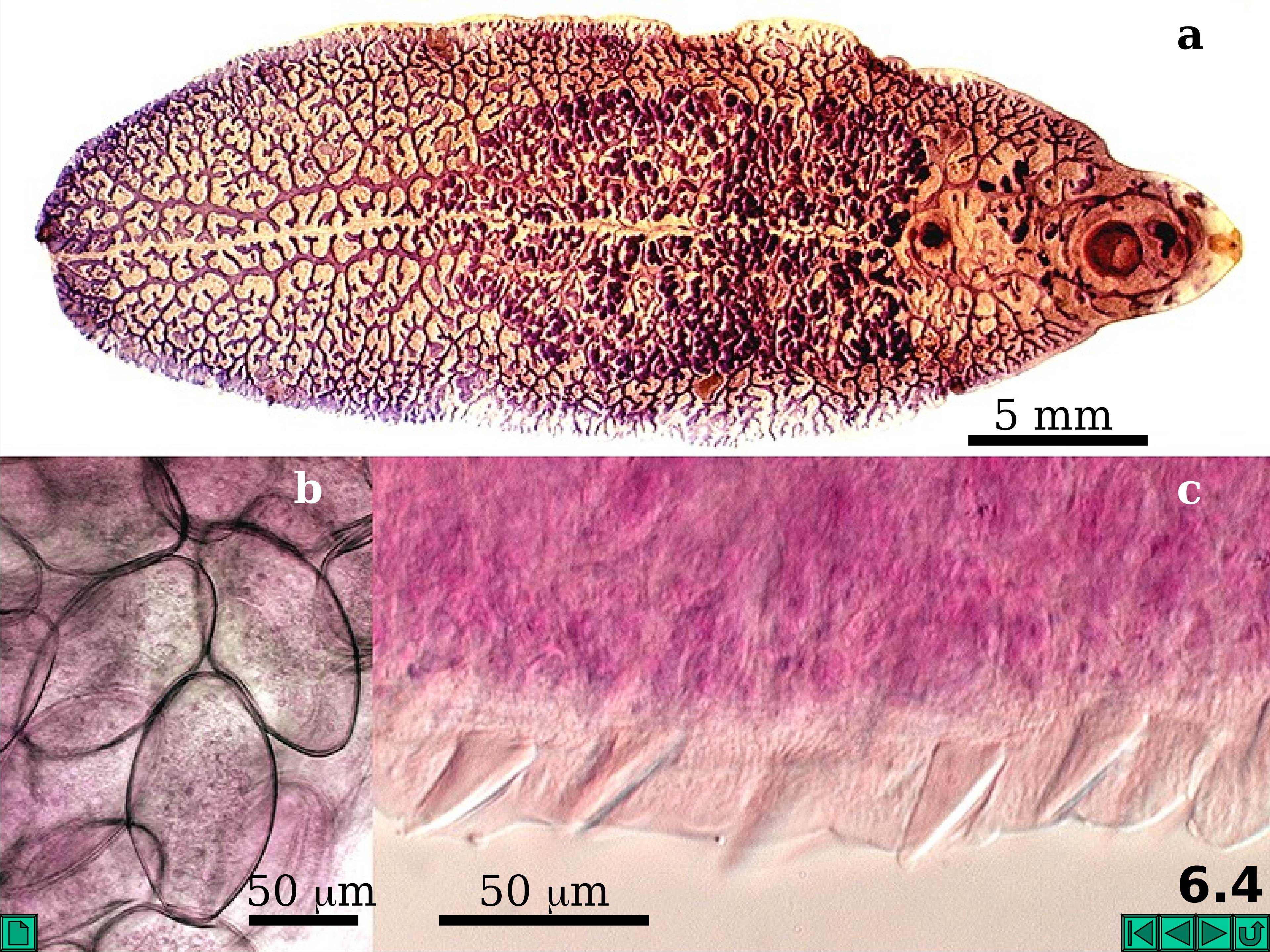
6.2 *Heterophyes heterophyes*. **a.** Adult worm. Heterophyids are extremely small, teardrop-shaped flukes occurring in the intestine of piscivorous birds and mammals. *H. heterophyes* occurs in Asia, but other species occur worldwide. Infections are contracted by eating uncooked fish infected with metacercariae. Many piscivorous mammals and birds serve as reservoir hosts. The mass posterior to the acetabulum is a gonotyl, a genital sinus with sucker. For a labeled photo of the adult, click here. Although heavy infections may cause diarrhea, the real concern is that adult worms may penetrate into the mucosa, resulting in deposition of worms and eggs in ectopic locations, e.g., the heart or brain. Such infections may be responsible for some cases of cardiac failure i Philippines. **b.** Eggs in uterus. These appear similar to eggs of *Clonorchis sinensis*. **c.**


a
5 mm
b
100 µm
c
50 µm

6.3

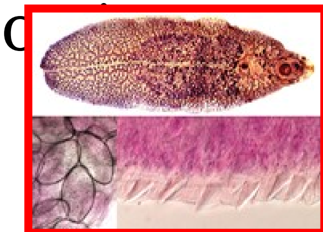
6.3 *Fasciolopsis buski*. **a.** Adult worm. This giant (up to 75 mm) fasciolid intestinal fluke is contracted in Asia by eating uncooked aquatic plants on which metacercariae have encysted. Dogs and pigs serve as reservoir hosts. Heavy infections can cause diarrhea, intestinal obstruction, and systemic toxicity, which may be fatal. Tandem, dendritic testes are faintly visible posteriorly. Unlike the related *Fasciola hepatica*, *F. buski* possesses unbranched intestinal ceca, and does not possess “shoulders” at the anterior end. Extensive vitelline glands occupy the lateral margins, and the gravid uterus is visible at the anterior end. For a labeled photo of the adult, click here. **b.** Eggs in uterus. **c.** Tegument, showing absence of spines.

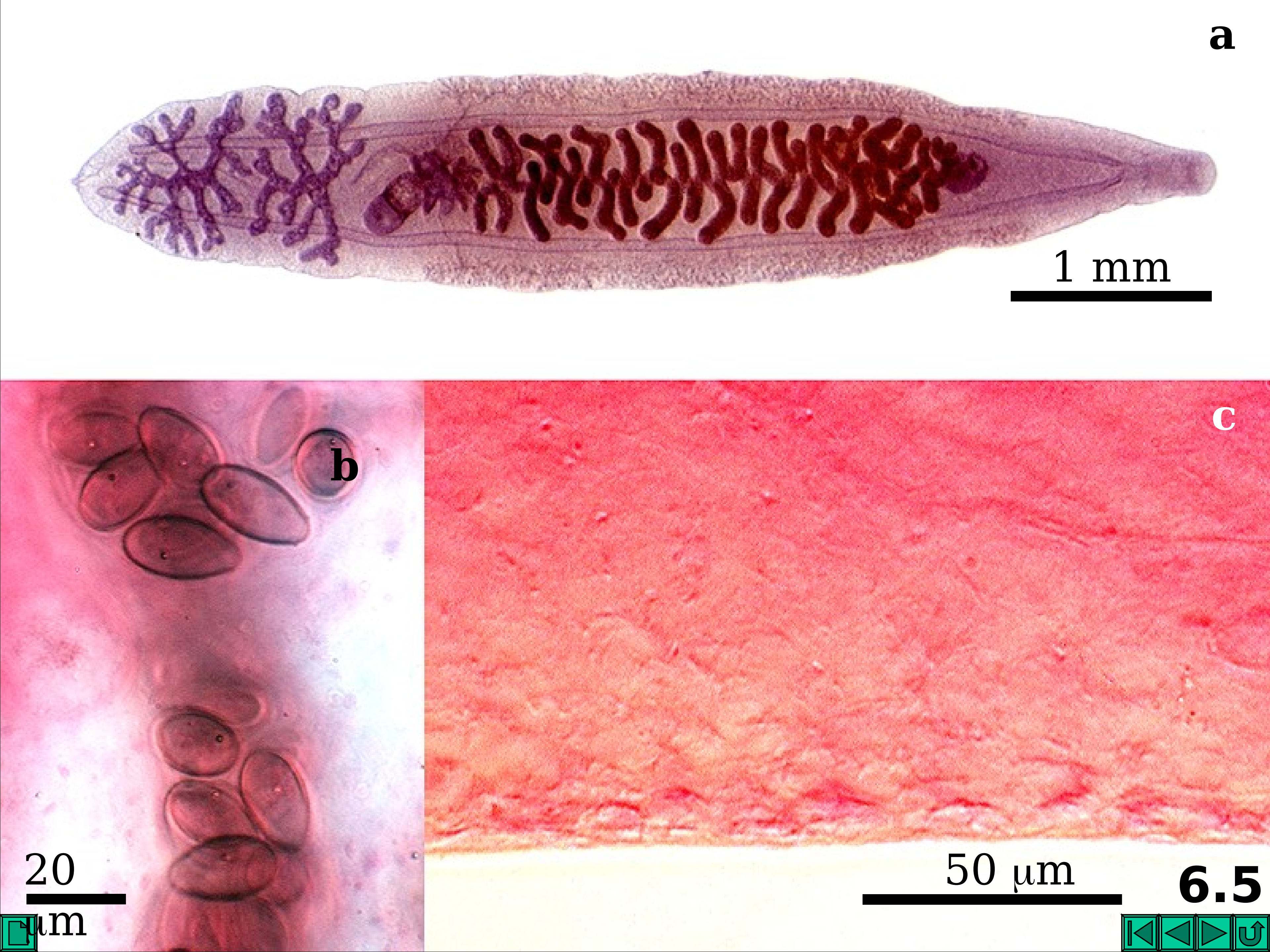



a
5 mm
b
50 µm
c
50 µm

6.4

6.4 *Fasciola hepatica*. **a.** Adult worm. This large (up to 30 mm) liver fluke has a worldwide distribution. Infections are contracted by eating uncooked aquatic plants on which metacercariae have encysted. Sheep and cattle are reservoir hosts. Juvenile worms cause anemia, damage to the liver parenchyma, and may lodge in ectopic locations, e.g., the brain or eye, whereas adults damage the bile ducts. This species can be recognized easily by its cephalic cone and "shoulders," as well as the highly branched intestinal ceca, clearly visible at the posterior end. Two darkly stained, tandem, dendritic testes occur in the middle of the body. For a labeled photo of the adult, click here. **b.** Eggs in uterus, similar to those of *Fasciolopsis buski*. **c.** Tegument, sho spines.

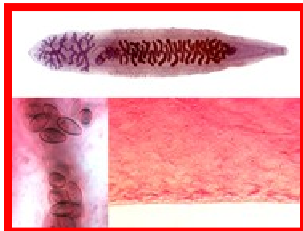


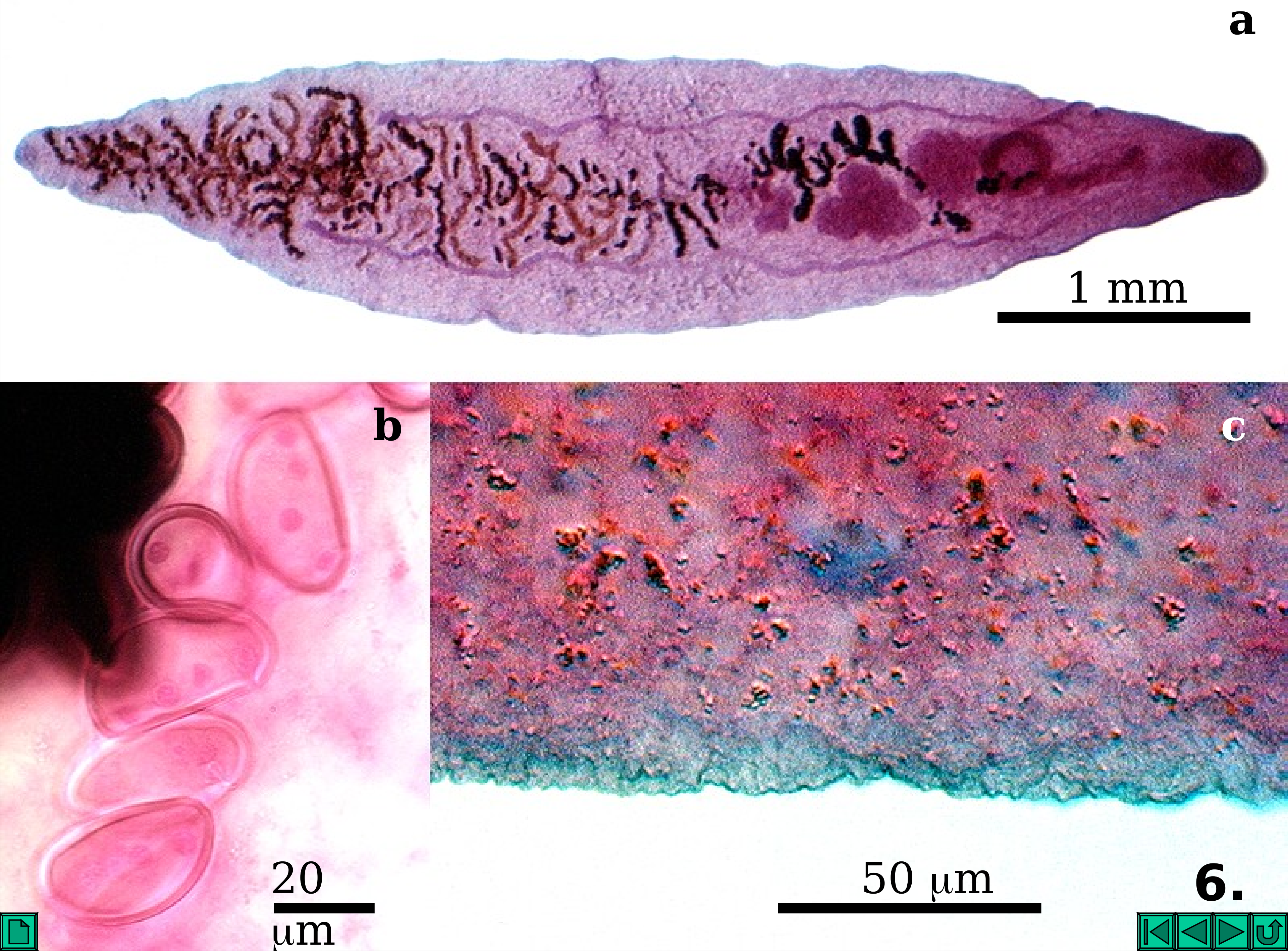

a
1 mm
b
c
20 µm
50 µm

6.5

6.5 *Clonorchis sinensis*. **a.** Adult worm. Infections with this liver fluke are contracted in Asia by eating uncooked freshwater fish in which metacercariae have encysted. Piscivorous mammals can serve as reservoir hosts. Although the liver parenchyma is not invaded, heavy infections may cause such damage to the bile ducts that jaundice, hepatomegaly, ascites, and death occur. Note the posterior, tandem, dendritic testes, the relatively large seminal receptacle anterior to the testes, the gravid uterus, and vitelline glands, confined to the middle of the body. For a labeled photo of the adult, click here. **b.** Eggs in uterus. **c.** Tegument, showing absence of spines.

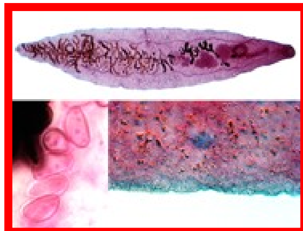
- back to adult of *Dicrocoelium dendriticum*

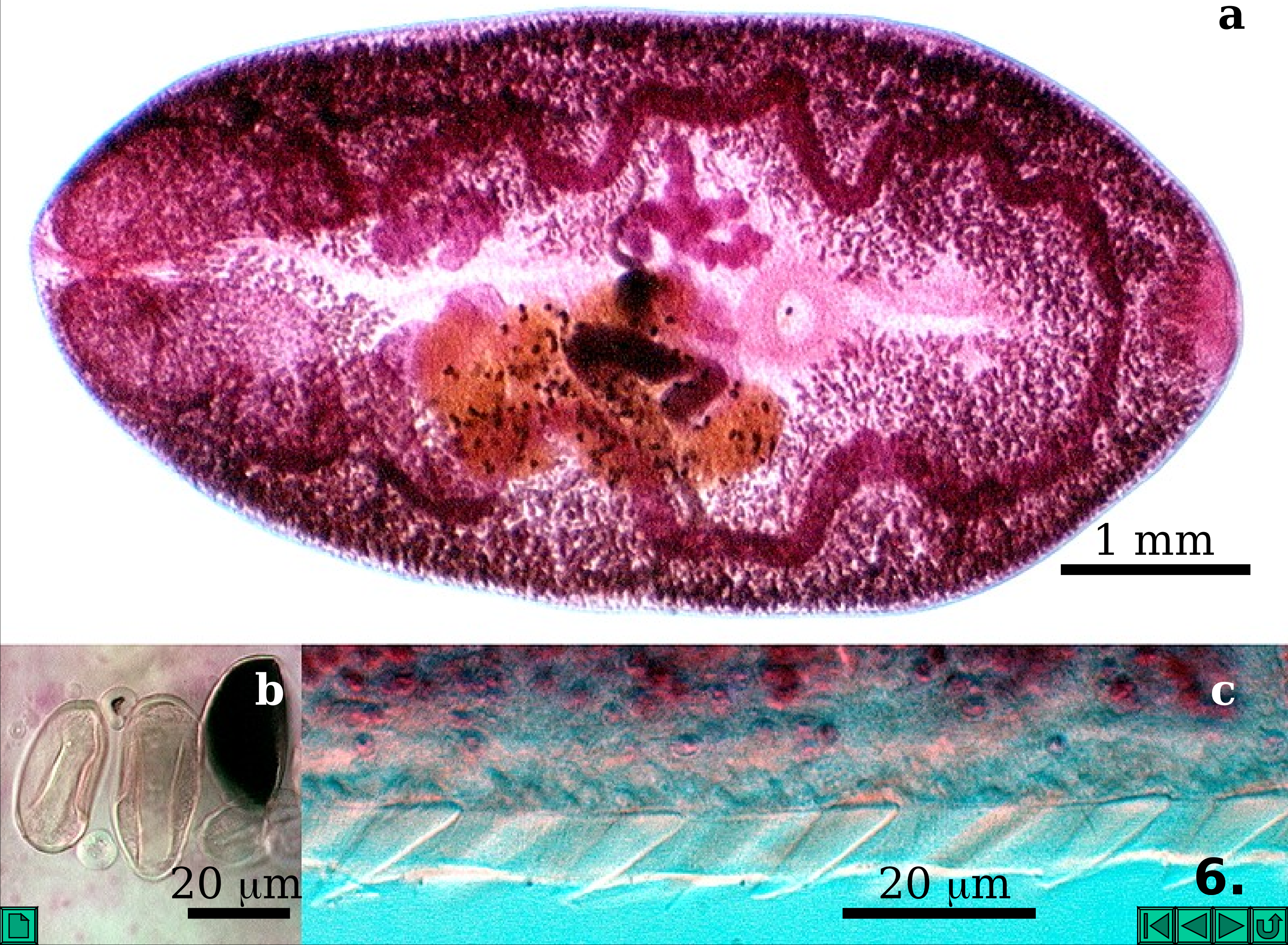



a
1 mm
b
c
20 µm
50 µm

6.

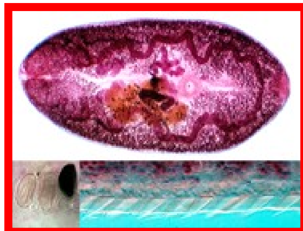
6.6 *Dicrocoelium dendriticum*. **a.** Adult worm. This liver fluke occurs in Europe, Asia, and N. America. It has an unusual terrestrial life cycle, and infections are contracted by eating ants infected with metacercariae. Infected ants display negative geotaxis during cool times of the day, causing them to crawl up blades of grass where they may be eaten by sheep and cattle. Thus, human infections are rare, but can mimic biliary disorders seen with other liver flukes. Note pointed ends of body, and extensive posterior uterus (unlike that of *Clonorchis sinensis*, with which it may be confused). For a labeled photo of the adult, click here. **b.** Eggs in uterus. **c.** Tegument, showing absence of spines.

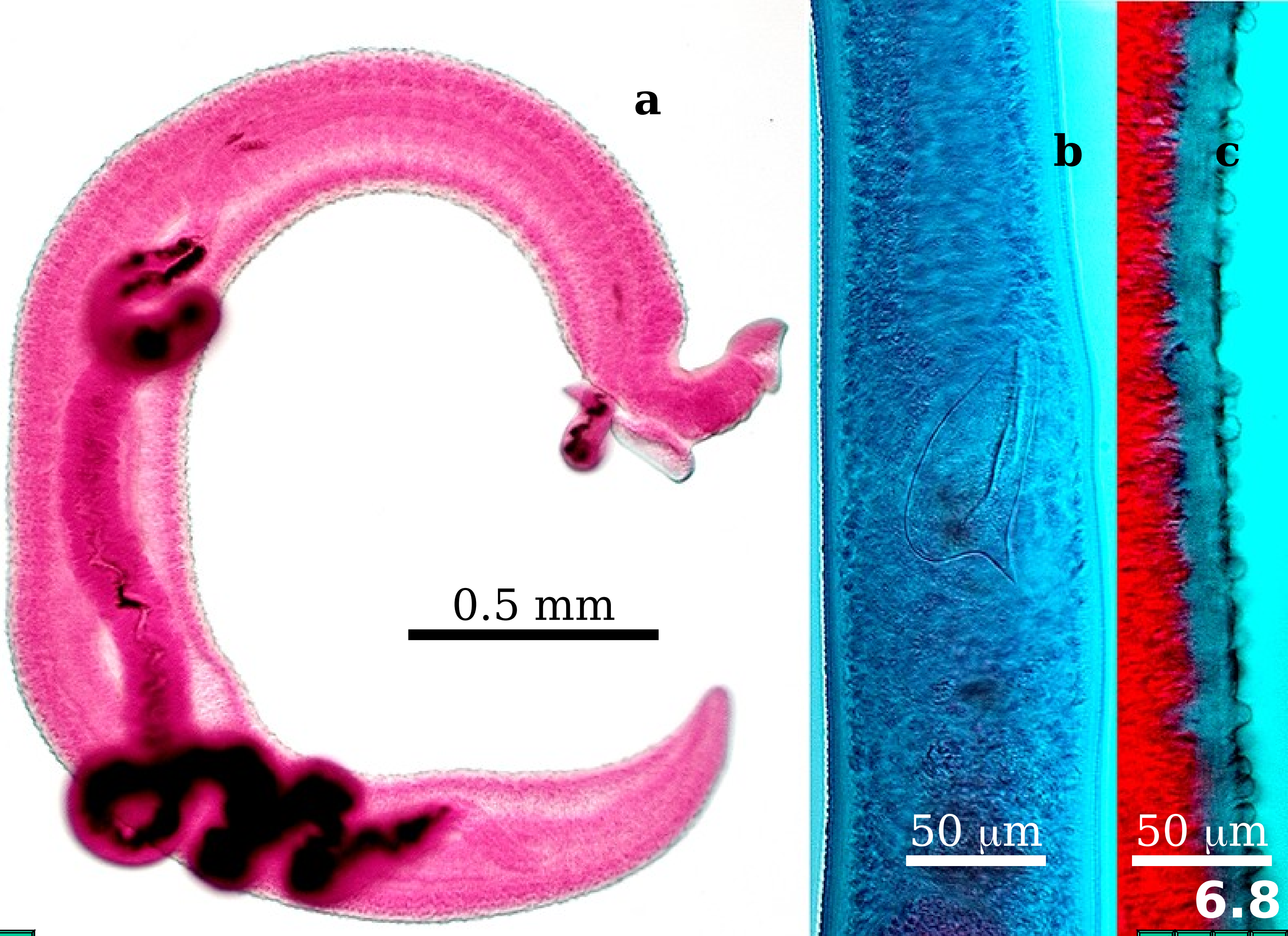



a
1 mm
b
20 µm
c
20 µm

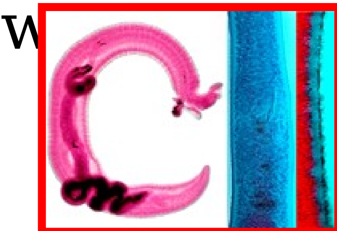
6.

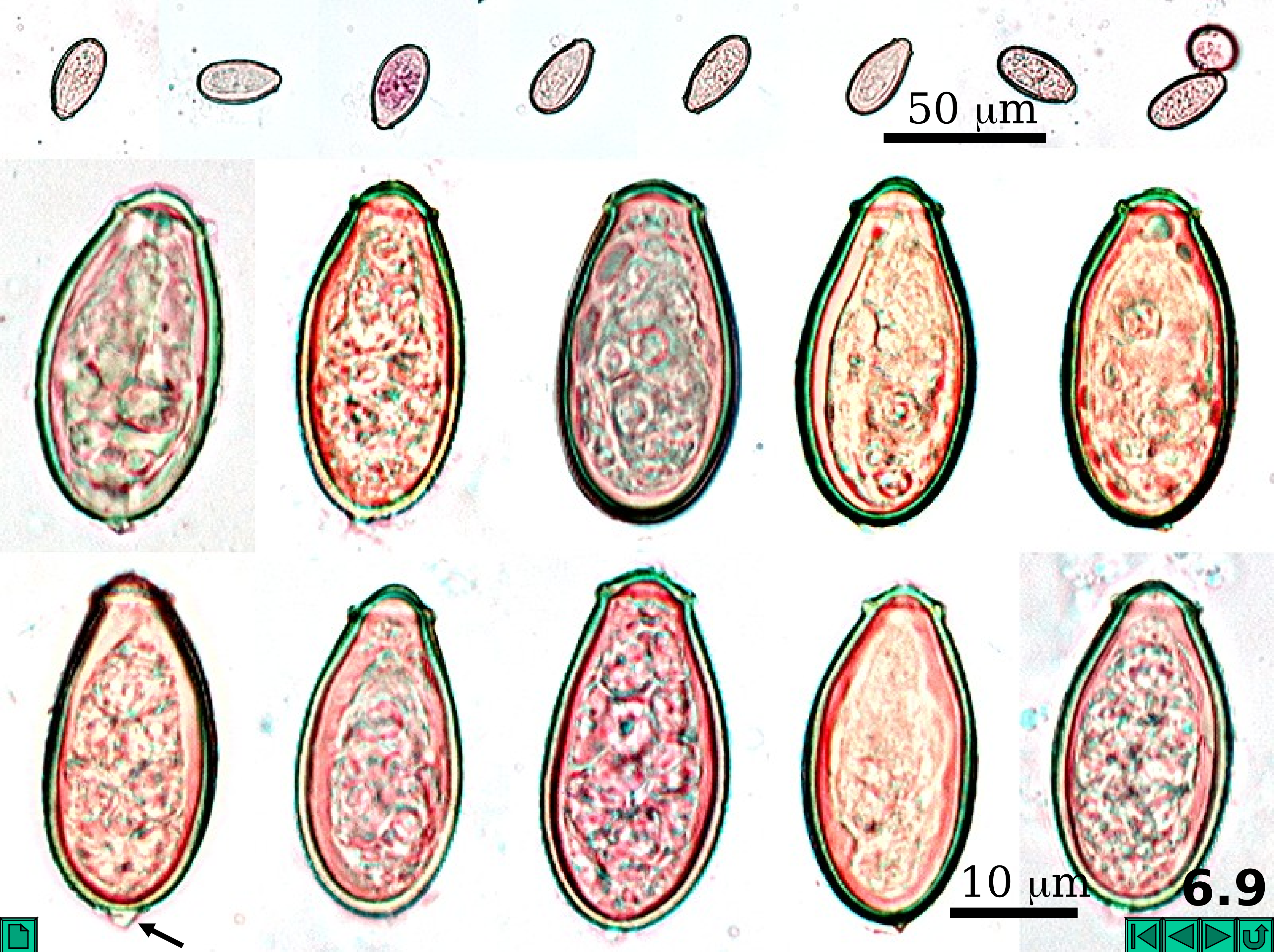
6.7 *Paragonimus westermani*. **a.** Adult worm. Infections with this lung fluke are contracted in Asia, the S. Pacific, and S. America by eating uncooked freshwater crabs that are infected with metacercariae. Numerous mammals, especially cats, serve as reservoir hosts. The lung lesions containing worm pairs result in hemoptysis, chronic cough, and frequent bacterial superinfection. Also, the juvenile worms may travel to ectopic locations, e.g., the brain, causing seizures. Note the coffee-bean shape, long, wavy ceca, adjacent, branched testes, and off-centered, lobate ovary. For a labeled photo of the adult, click here. **b.** Eggs in uterus, collapsed during specimen processing. **c.** Tegument, showing spines.




a
b
c
0.5 mm
50 µm
50 µm

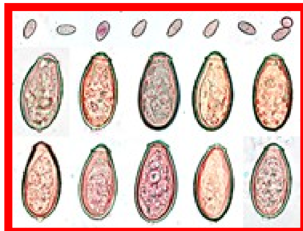
6.8 *Schistosoma mansoni*. **a.** Adult worms. Infections with this blood fluke are acquired in Africa, S. America, and parts of the Caribbean when cercariae released from *Biomphalaria* spp. snails penetrate through the skin. Thus, no metacercarial stage is involved. Eggs deposited by the female in mesenteric veins are swept into the liver and elicit an inflammatory response, resulting in fibrosis, which may cause portal hypertension and hemorrhage of collateral vessels. Intestinal lesions may also occur. Note that the worms have separate sexes, and that the female is wrapped within the gynecophoral canal of the male. **b.** Single egg within uterus. **c.** Male tegument, showing papillae. The tegument of *S. haematobium* (which occurs in Africa) has few papillae, and that of *S. japonicum* (in Asia) is smooth.

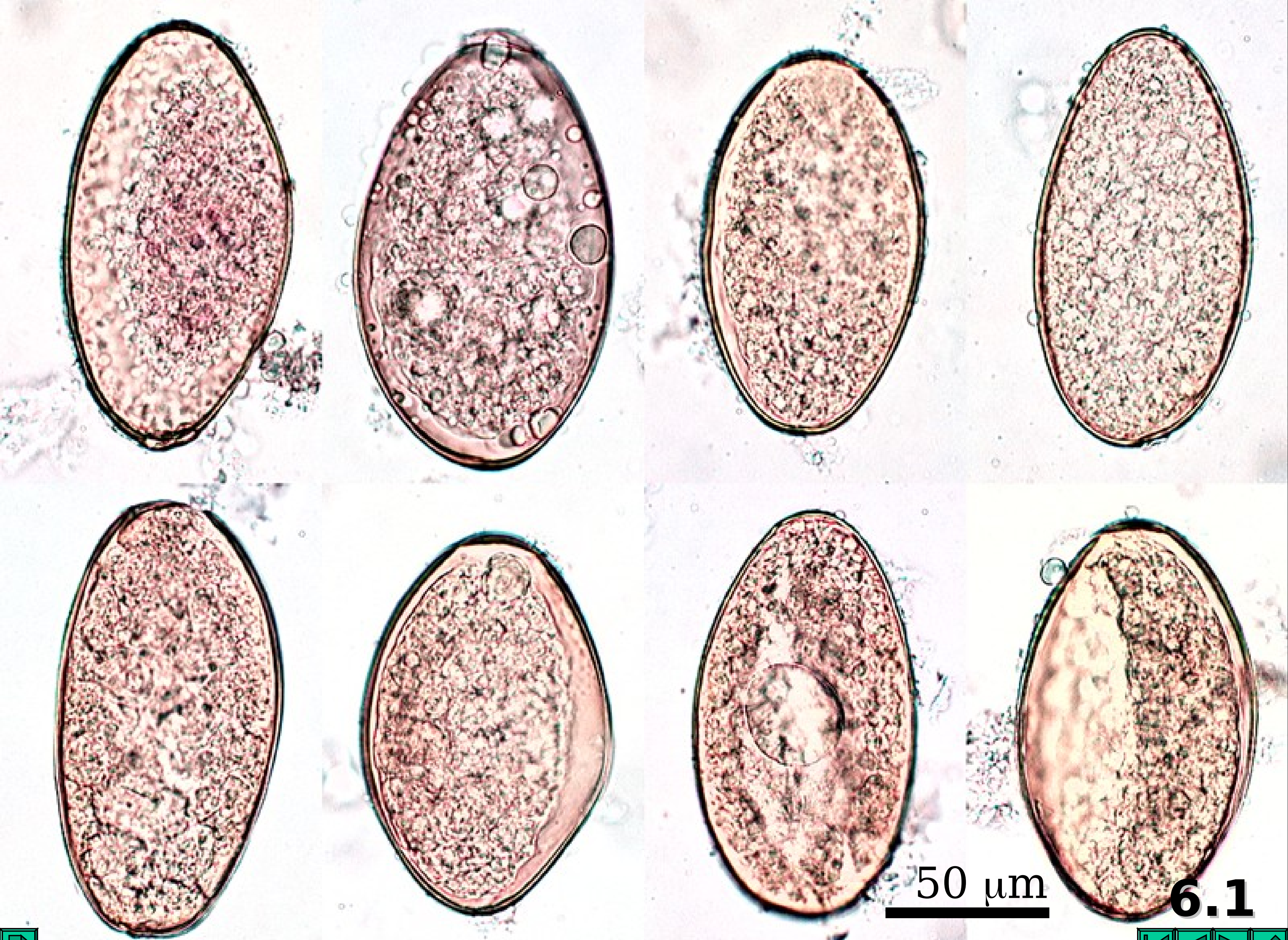



50 μm
10 μm

6.9 Eggs of *Clonorchis sinensis*. Top row photographed at the same magnification as eggs of other species in following figures. The small size of this egg is a key diagnostic feature. Second and third rows photographed at a higher magnification, to show the operculum sitting in a rim, and a fully formed miracidium, which does not hatch from the egg until ingested by a snail. A small abopercular knob (arrow) is visible on some eggs.

- back to adult of *Clonorchis sinensis*
- back to adult of *Heterophyes heterophyes*

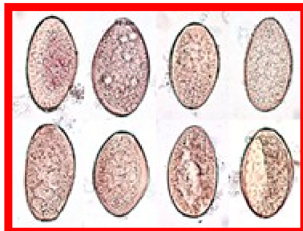


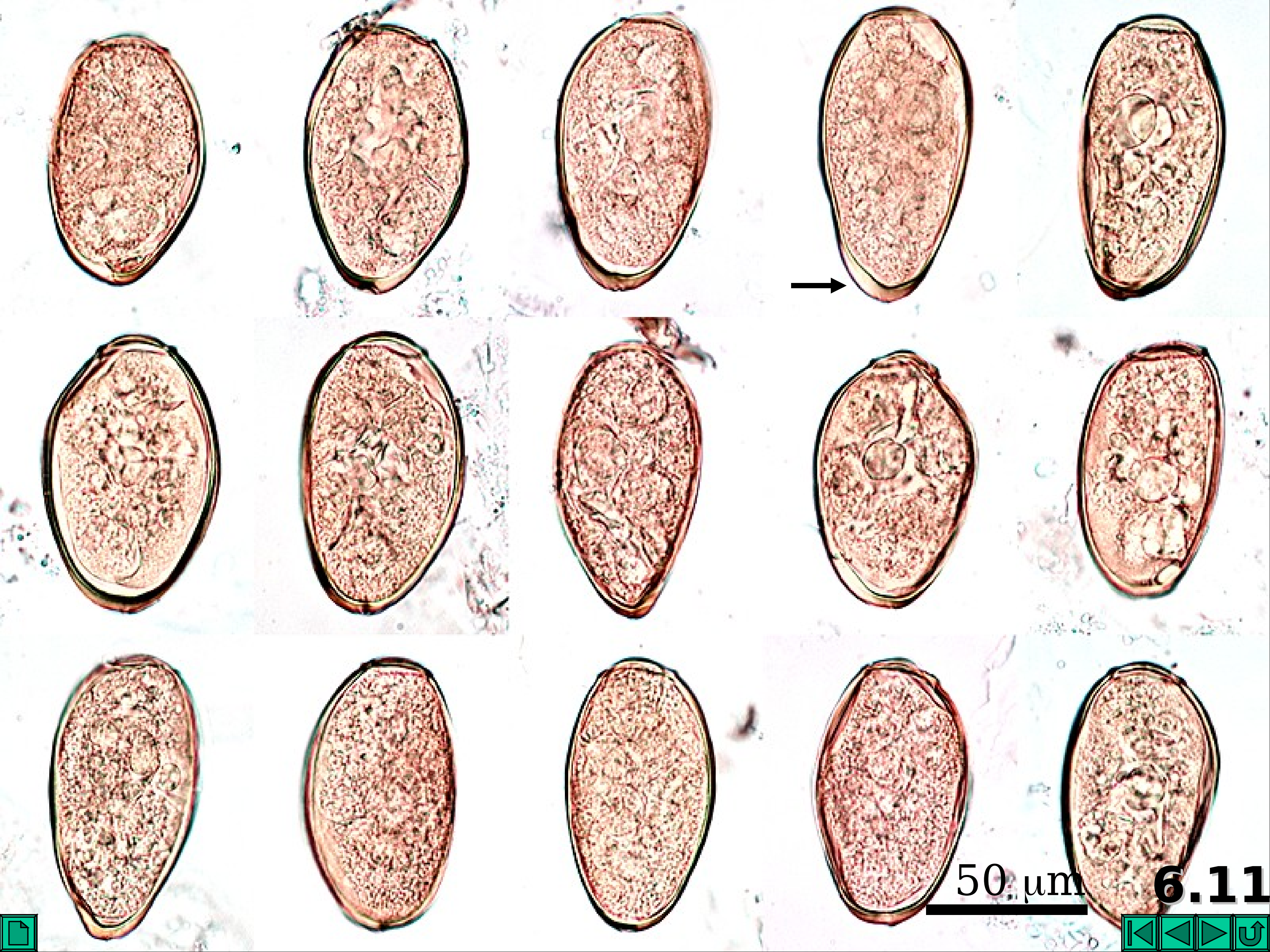


6.1

6.10 Eggs of *Fasciola hepatica.* Note the unembryonated condition, smooth oval shape, large size, and relatively narrow (compared to eggs of *Paragonimus westermani*) operculum. Usually, yolk granules completely fill the immature egg.

- back to adult of *Fasciola hepatica*
- back to eggs of *Echinostoma paraensei*

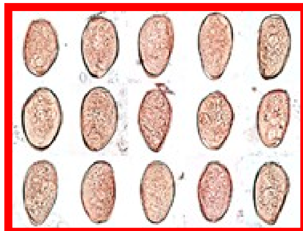


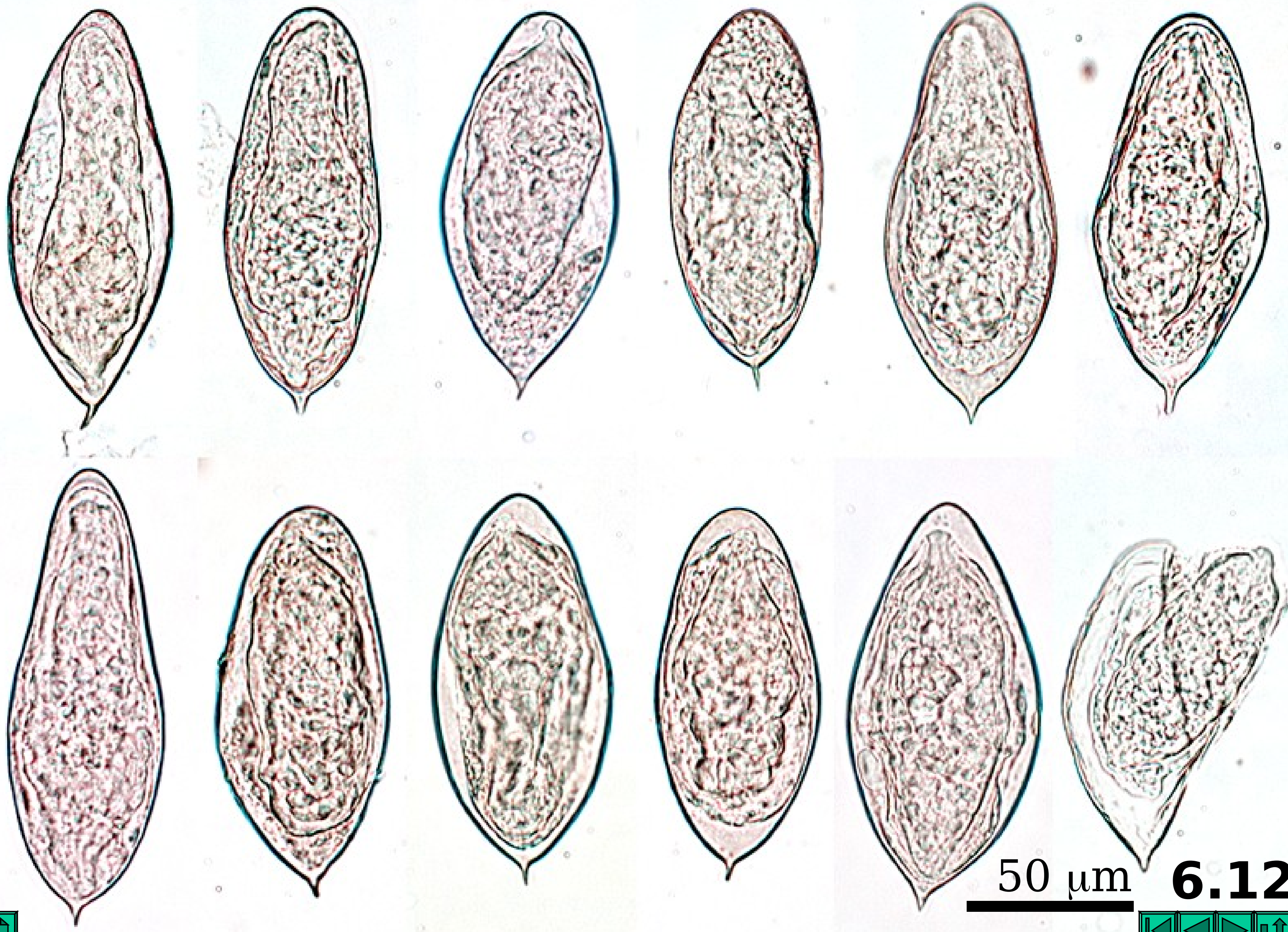


6.11

6.11 Eggs of *Paragonimus westermani*. This egg would be found in human sputum, but also occurs in feces when swallowed. Note the thick abopercular wall (arrow), unembryonated condition, and relatively wide (compared to eggs of *Fasciola hepatica*) operculum, which sits in a rim.

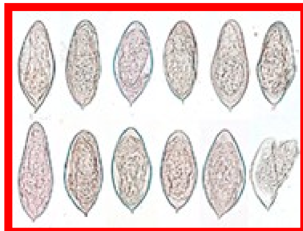
- back to adult of *Paragonimus westermani*
- back to lung lesions

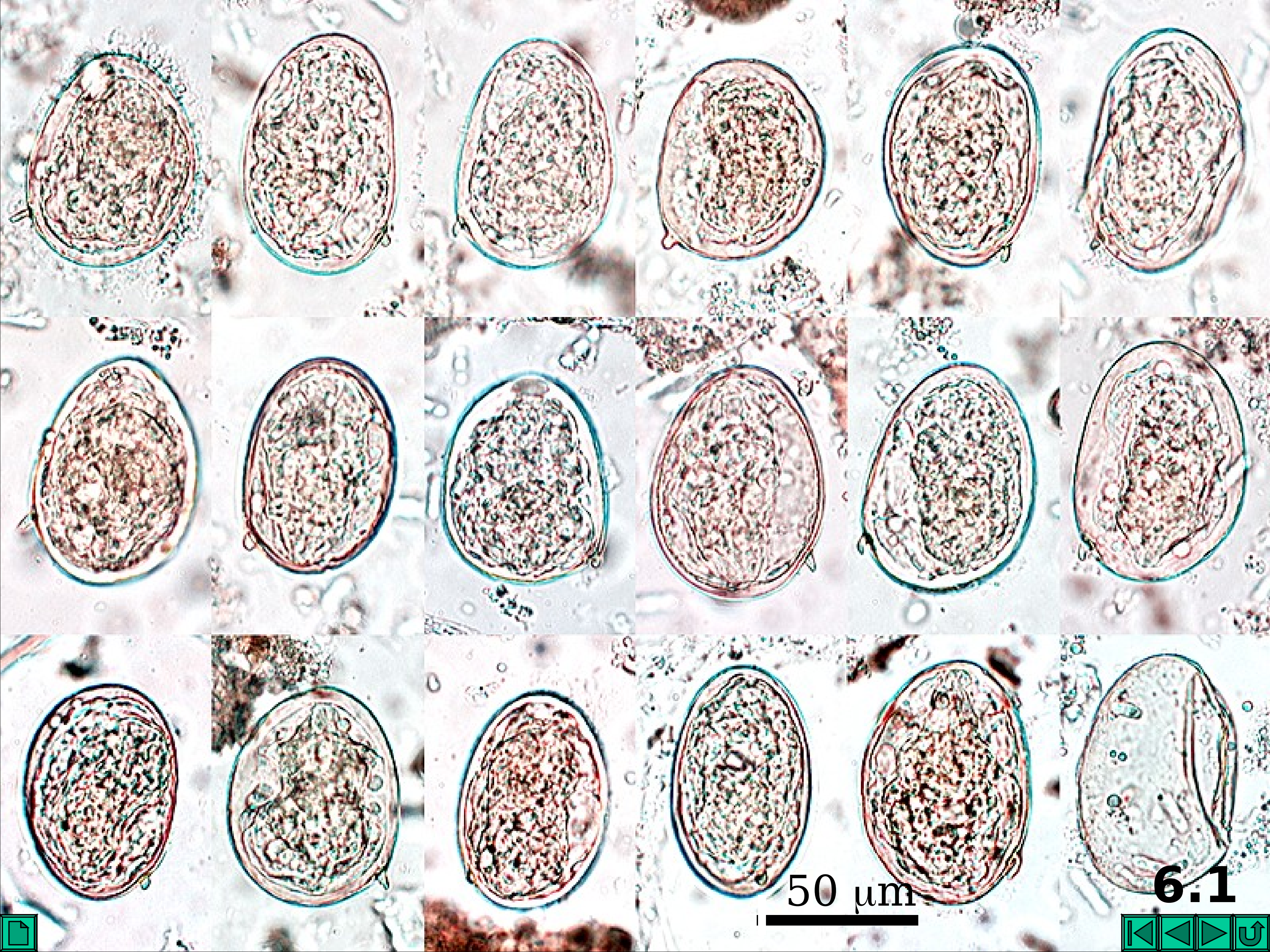




6.12

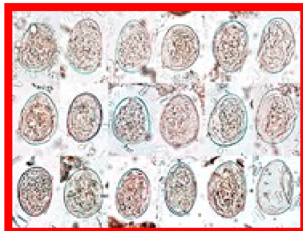
6.12 Eggs of *Schistosoma haematobium*. These would be found mainly in urine, because the adult worms inhabit veins surrounding the bladder, but eggs also are found in feces. They are easily identified by the terminal spine and fully formed miracidium, which hatches immediately in fresh water through a tear in the egg shell (lower right photo). *S. haematobium* occurs in Africa and the Middle East, and is transmitted by *Bulinus* snails. In addition to hematuria and fibrosis of the bladder and ureters, infections are associated with bladder cancer.

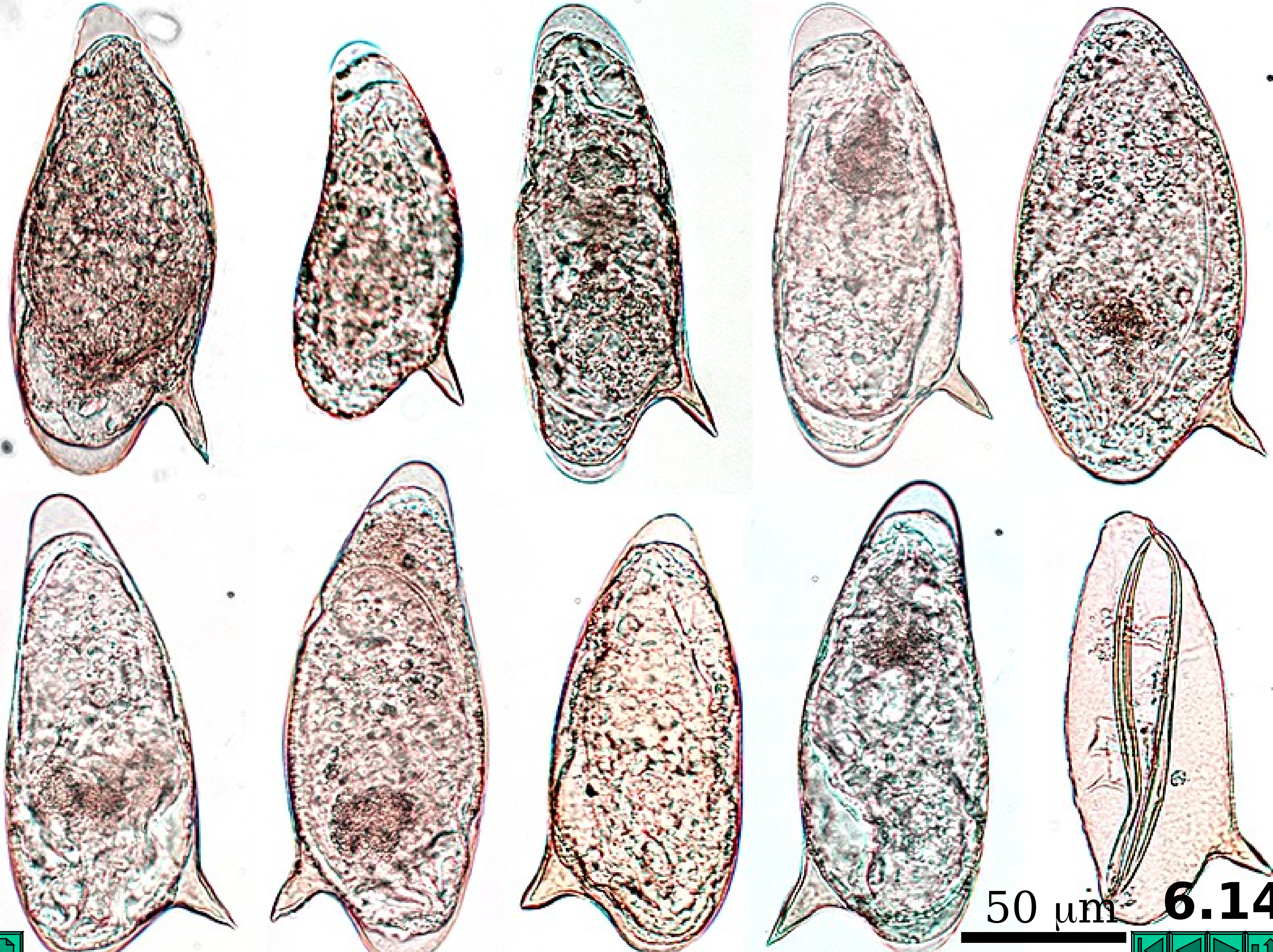




6.1

6.13 Eggs of *Schistosoma japonicum*. Note the fully formed miracidium, which hatches immediately in fresh water through a tear in the shell (lower right photo), and the minute lateral spine, which is not apparent in several photographs because it is not viewed in profile. This species, which occurs in Asia, is the most pathogenic of the human-infecting schistosomes due to the high egg production by females and the tendency of the small eggs to pass through the liver and enter the systemic circulation, causing pathology in other organs, especially the central nervous system. *S. japonicum* is transmitted by operculate snails in the genus *Oncomelania*.

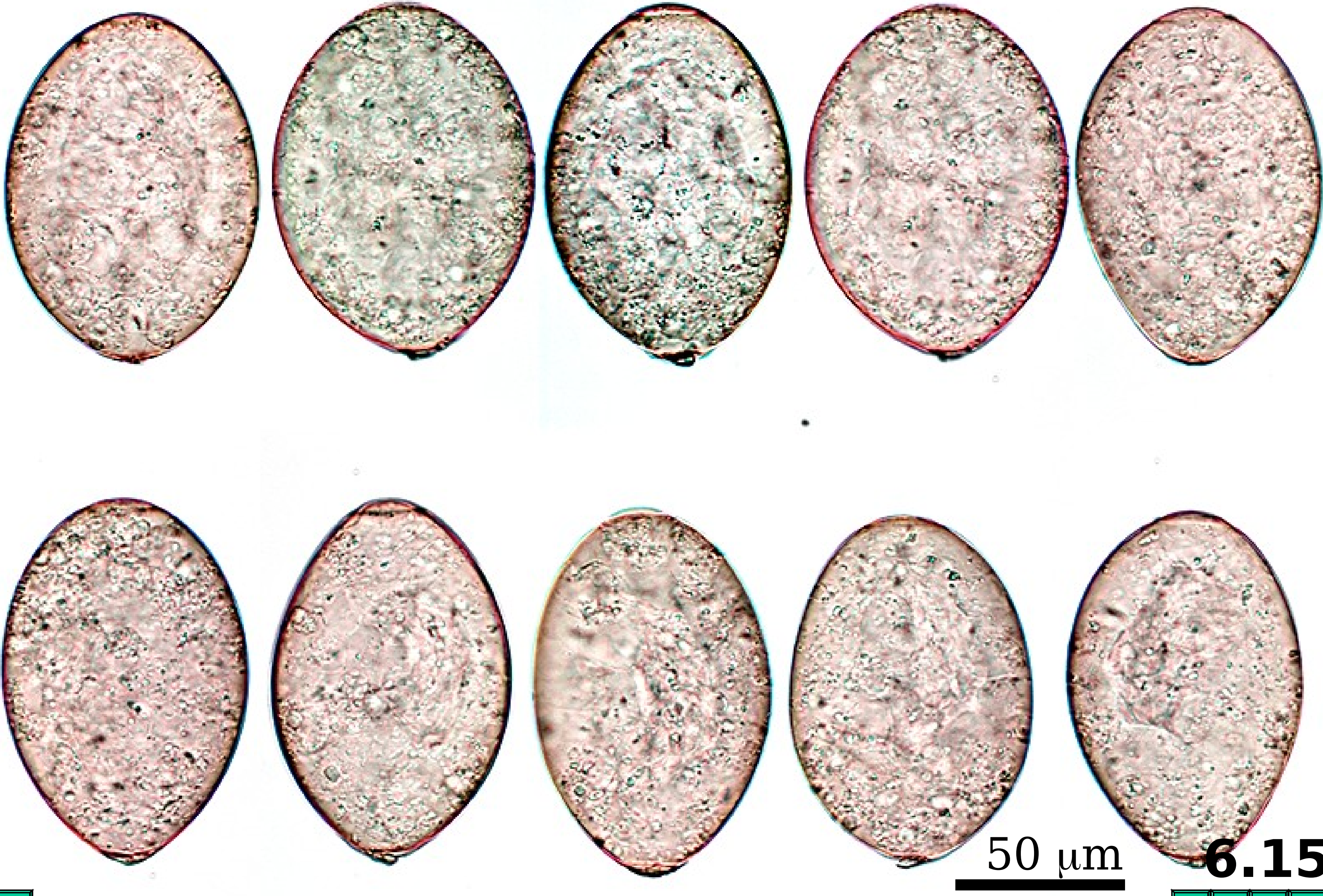




6.14

6.14 Eggs of *Schistosoma mansoni*. Eggs contain a fully formed miracidium, which hatches immediately in fresh water through a tear in the shell (lower right photo), and possess a large lateral spine, which may be inconspicuous if pointing straight up. This species is transmitted in Africa, the Caribbean, and Brazil by snails in the genus *Biomphalaria*. These eggs elicit granulomas in the liver, as well as intestinal lesions.

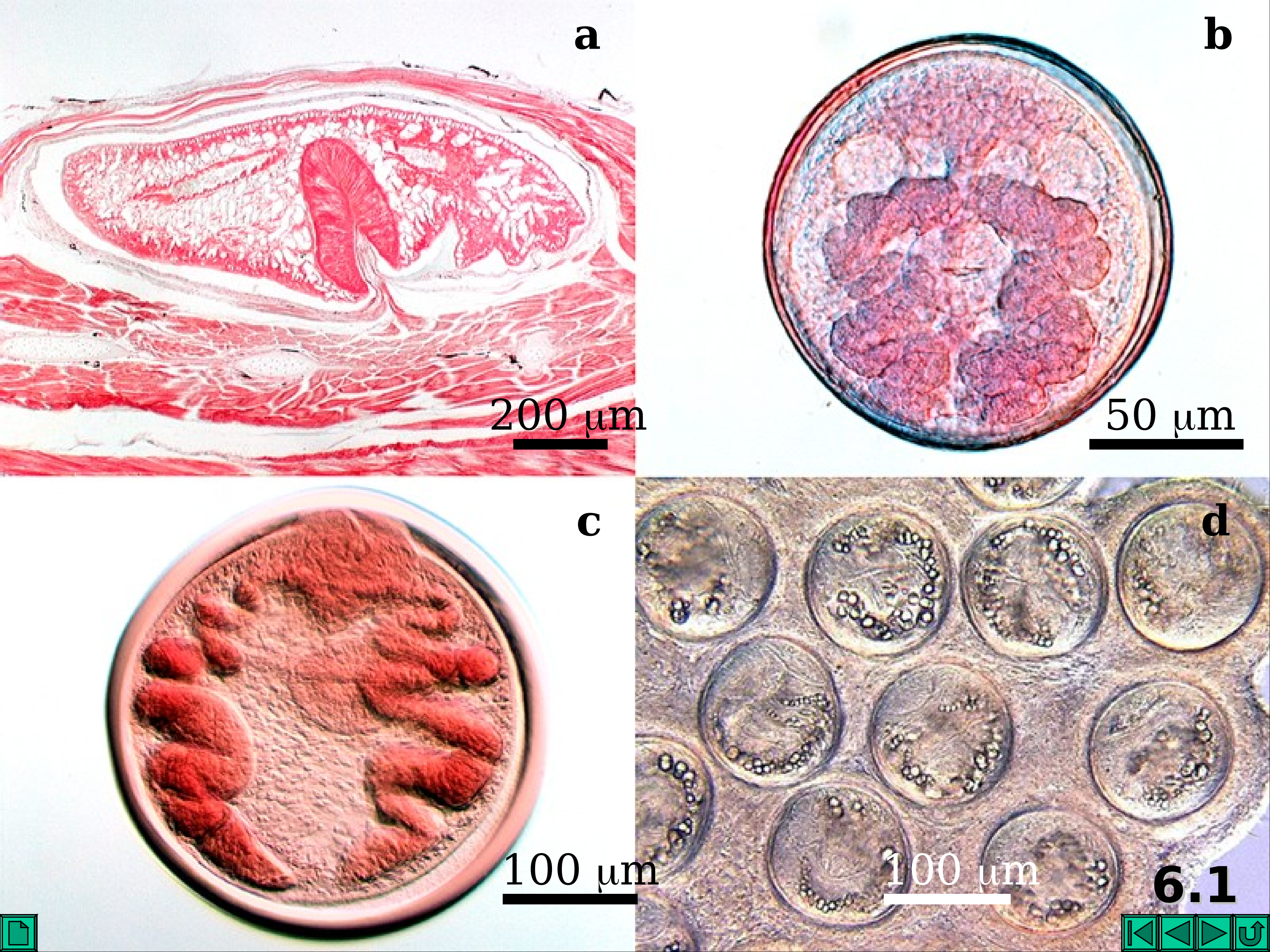
- back to adult of *Schistosoma mansoni*



6.15

6.15 Eggs of *Echinostoma paraensei*. These eggs are unembryonated when first deposited in the feces. A miracidium develops within two weeks and hatches through a small operculum. Compare with eggs of *Fasciola hepatica*.

- back to adult of *Echinostoma revolutum*

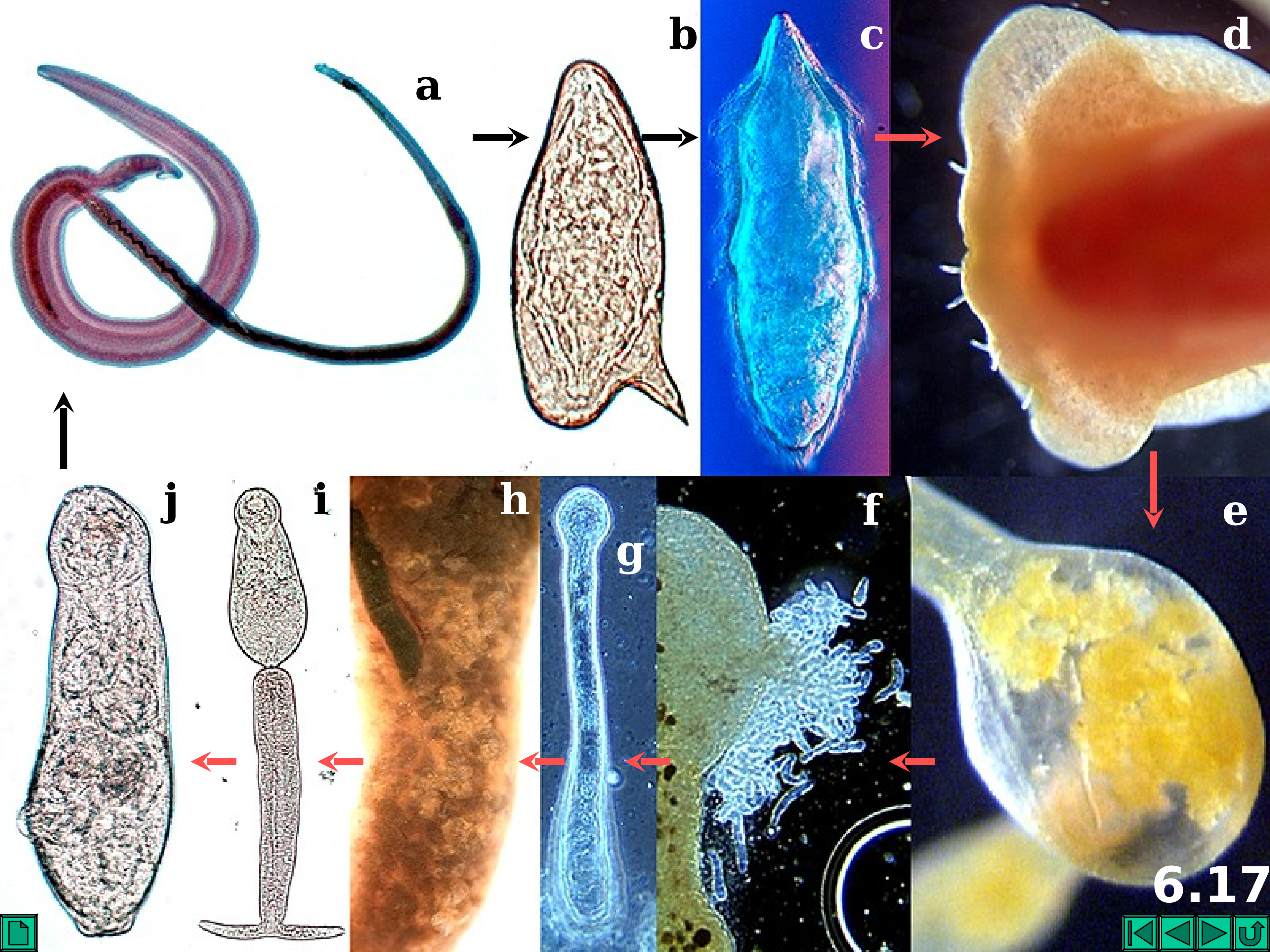

a
200 µm
b
50 µm
c
100 µm
d
100 µm

6.1

6.16 Metacercariae. These encysted stages occur in the life cycle of nearly all trematodes except for the schistosomes. **a.** Histological section of *Clinostomum,* a parasite of bird definitive hosts, in fish muscle. **b.** *Fasciola hepatica,* metacercariae of which would be found on the surface of aquatic plants, e.g., watercress. **c.** *Paragonimus westermani,* from the muscle of infected crab. **d.** *Echinostoma paraensei,* from the pericardial cavity of a snail. Note the thick tunic of snail hemocytes surrounding each echinostome metacercaria.

6.16d from J.T. Sullivan, *Electronic Atlas of Parasitology, 1.0.* Copyright © 1999 McGraw-Hill, Inc., Dubuque, IA. Reprinted by permission.

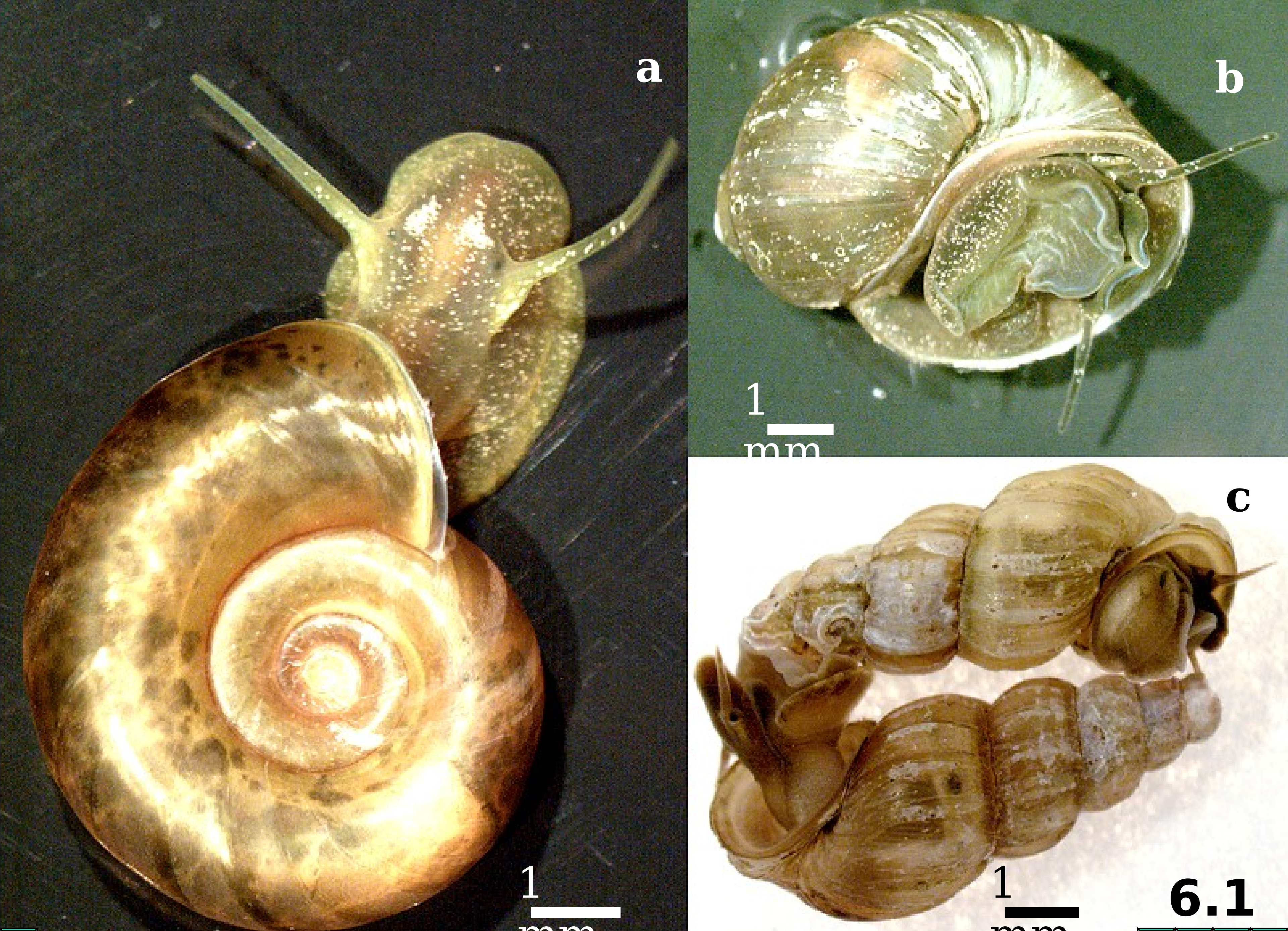
- back to adult of *Echinostoma revolutum*
- back to adult of *Fasciola hepatica*
- back to adult of *Paragonimus westermani*


a
b
c
d
e
f
g
h
i
j

6.17

6.17 Life cycle of *Schistosoma mansoni*. **a.** Adult worms *in copula*. **b.** Egg in feces. Eggs hatch immediately upon reaching fresh water, releasing a miracidium. **c.** Miracidium, which must penetrate into a susceptible snail within several hours. **d.** Miracidia penetrating head foot of *Biomphalaria glabrata*. Each miracidium transforms into a single mother sporocyst at the site of penetration. **e.** Mother sporocyst in tentacle of *B. glabrata* several weeks after penetration of the miracidium. **f.** Squash of tentacle infected with mother sporocyst, showing released daughter sporocysts. **g.** Higher magnification of daughter sporocyst, showing typical elongation and enlargement of anterior end. These migrate posteriorly to the digestive gland. **h.** Digestive gland of infected snail (green), largely replaced by daughter sporocysts (yellow). These give rise to cercariae. **i.** Cercaria, with characteristic forked tail. These attach to hu
skin, drop their tail, penetrate, and are then calle
chistosomula. **j.** Schistosomulum, which pairs w

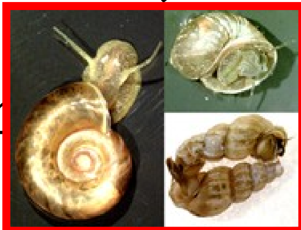
- back to adult of *Schistosoma mansoni*

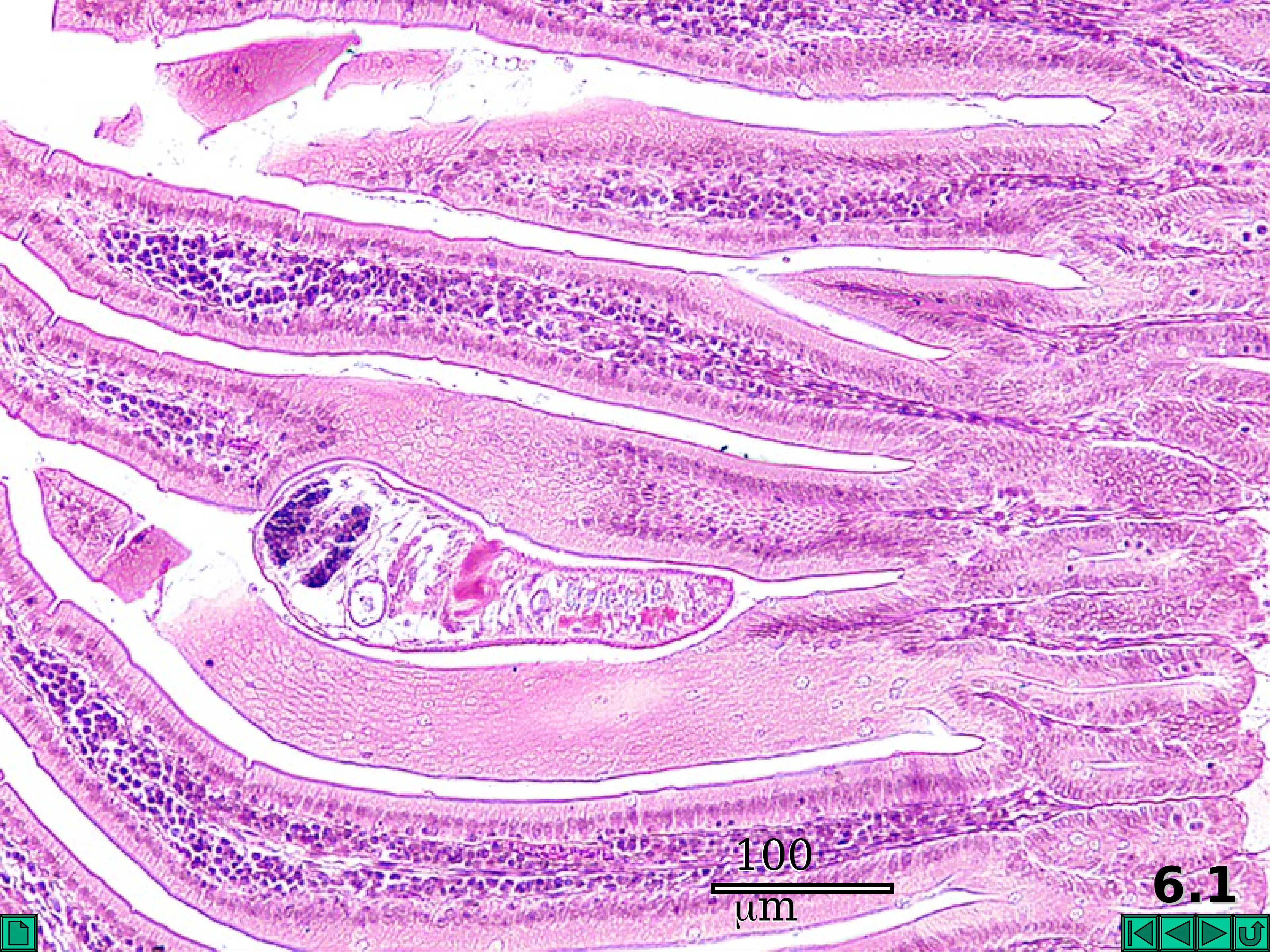

a
b
1 mm
c
1 mm
1 mm

6.1

6.18 Snail vectors of schistosomiasis. **a.** *Biomphalaria glabrata*, intermediate host of *Schistosoma mansoni* in the New World. Note the planospiral shell and the red tissue coloration, due to free hemoglobin in the hemolymph, a characteristic of planorbid snails (i.e., in the family Planorbidae). These snails can grow to well over 20 mm in diameter. Since they are hermaphroditic and can self fertilize, and because they can survive desiccation by entering a state of dormancy, they are difficult to control with molluscicides. **b.** *Bulinus truncatus* from Egypt, the intermediate host of *S. haematobium*. Note the more conical, globose shell. This snail is also a planorbid. **c.** *Oncomelania hupensis*, the intermediate host of *S. japonicum*. This snail is much smaller than the other two (only several mm long), and unlike them lacks hemoglobin, has separate sexes, possesses a gill, and has an operculum on its head foot that it uses to seal th aperture of its shell. Due to its operculum and

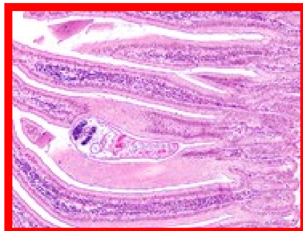
- back to eggs of *S. haematobium*, *S. japonicum* or to *eggs* / adults / life cycle of *S. mansoni*

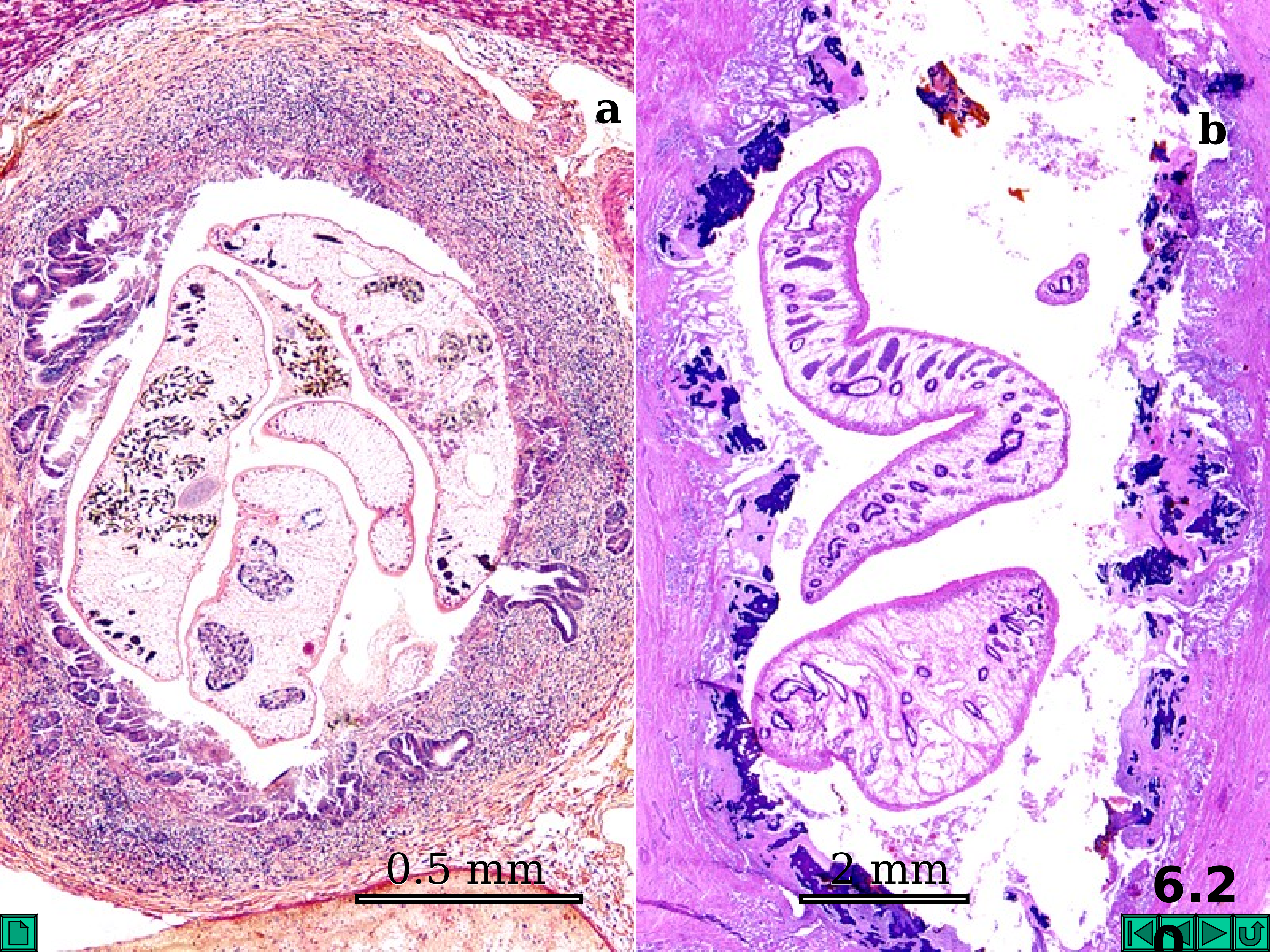




6.1

6.19 *Phagicola nana*, a heterophyid whose metacercariae occur in estuarine fishes along the eastern U.S. coast, in the intestine of an experimentally infected hamster. Note the very small size of the worm. Although this species apparently does not invade the mucosa, others, such as *Heterophyes heterophyes* and *Metagonimus yokagawi*, may penetrate through the crypts and into the mucosa, resulting in ectopic adults and eggs throughout the body.





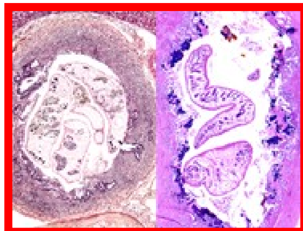
6.20

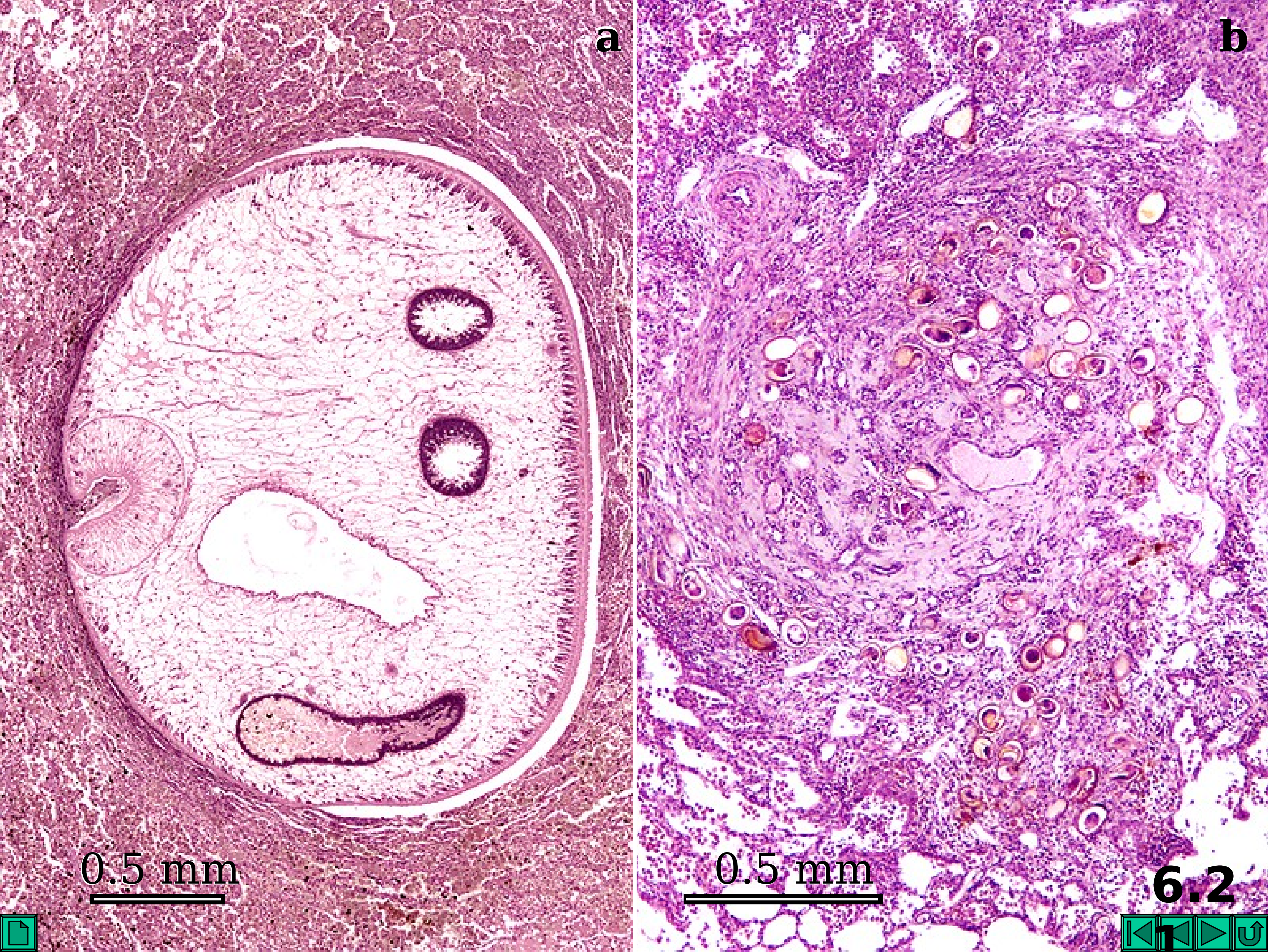
6.20 Histological sections of bile ducts infected with adults of liver flukes. **a.** Infection with *Clonorchis sinensis.* These worms feed upon, and damage, the epithelium of the duct, which is eroded in some areas of this section. Note the inflammatory response in the lamina propria of the duct, which results in further tissue damage. Routine ingestion of uncooked freshwater fish harboring metacercariae can lead to infections with thousands of adults, resulting in biliary dysfunction, jaundice, ascites, and sometimes death. **b.** Infection with *Fasciola hepatica*. This species also damages the epithelium of the bile duct as adults, and damages the liver parenchyma during maturation of the juveniles.

- back to adult of *Clonorchis sinensis*
- back to adult of *Fasciola hepatica*

C.
sis

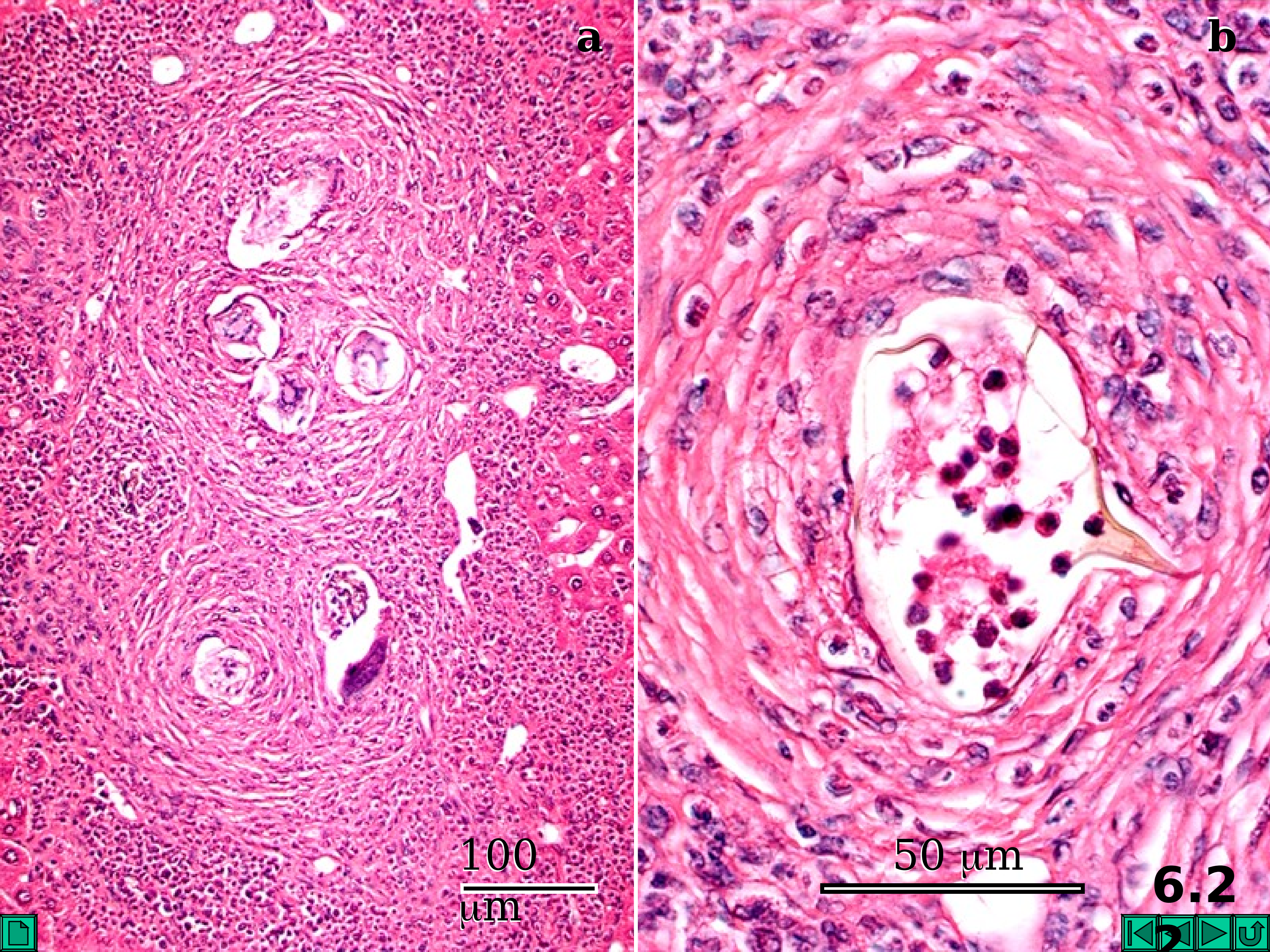
F. hepatica




a
b
0.5 mm
0.5 mm

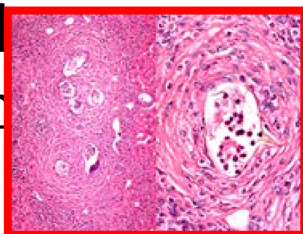
6.2

6.21 Pathology in lung infected with *Paragonimus westermani*. Adults of *P. westermani* live in fibrotic capsules in the lung parenchyma, usually in pairs, and deposit eggs which are coughed up into the pharynx. Significant damage results from compressed and ingested lung tissue, as well as from the inflammatory response against the worms and eggs. **a.** Cross section of single adult, adhering to lung tissue with its acetabulum. Note replacement of normal alveolar structure with the inflammatory response surrounding the worm. A lone alveolus appears in the upper left corner. **b.** Inflammatory response surrounding a cluster of eggs. Alveoli are seen only at the bottom of the photograph.

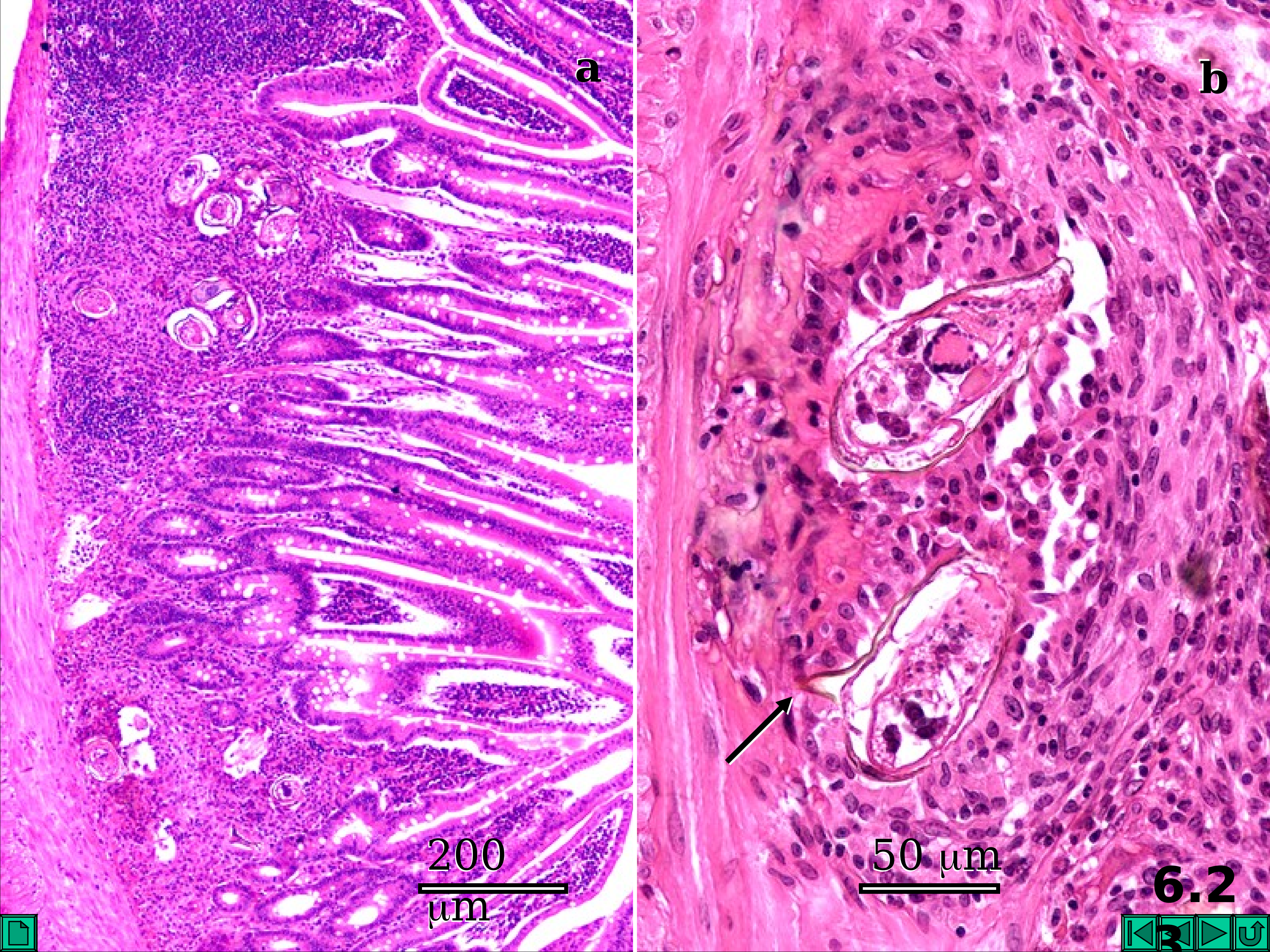

a
b
100 µm
50 µm

6.22

6.22 Histological section of liver from a mouse infected with *Schistosoma mansoni*. **a.** Low magnification view, showing two granulomas in the parenchyma. **b.** Higher magnification view of a single granuloma surrounding an egg, which has a clearly visible lateral spine. These granulomas protect the surrounding hepatocytes from lytic enzymes released by the egg, but occlude the sinusoids and presinusoidal capillaries through which blood must flow. As a result, pressure is elevated in the hepatic portal vein carrying blood from the intestine to the liver (portal hypertension), causing seepage of fluid into the abdominal cavity (ascites fluid). More importantly, thin-walled collateral vessels form to carry the blood around the liver blockage and back to th heart. If a large vessel bursts, especially in th wall of the esophagus (rupture of esophageal

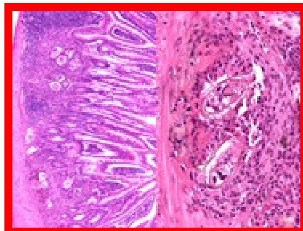


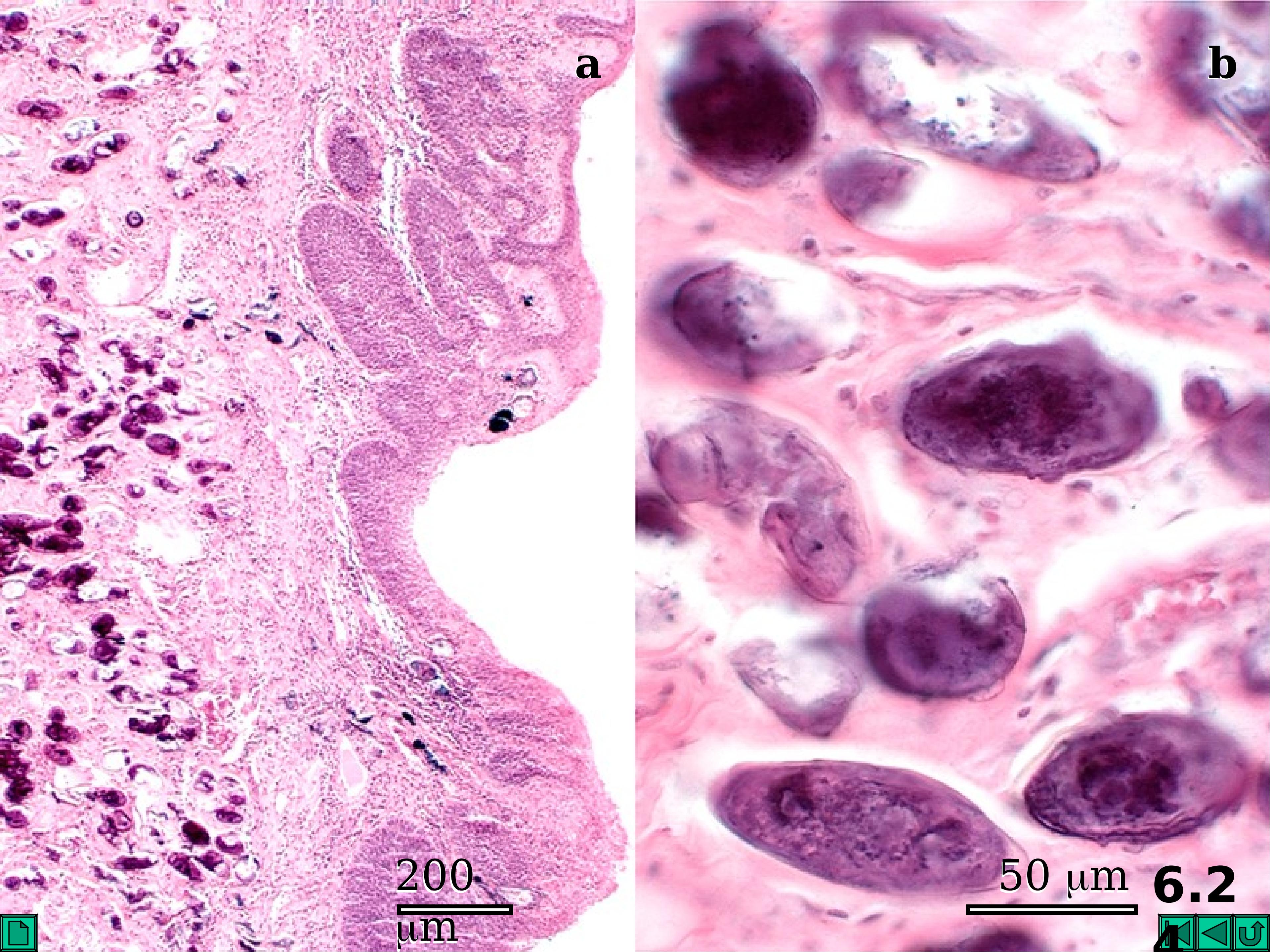
- back to adult of *Schistosoma mansoni*


a
200 μm
b
50 μm

6.23 Histological section of intestine from a mouse infected with *Schistosoma mansoni*. **a.** Masses of eggs in the submucosa of the small intestine. **b.** Higher magnification of two eggs surrounded by a granuloma. Note the lateral spine (arrow). In humans, the most severe intestinal lesions in the case of *S. mansoni* infections occur in the colon. Symptomatic intestinal schistosomiasis is most common with *S. japonicum*.

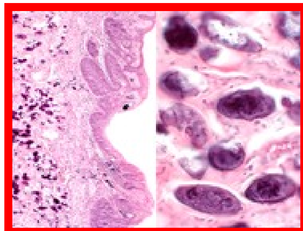
- back to adult of *Schistosoma mansoni*



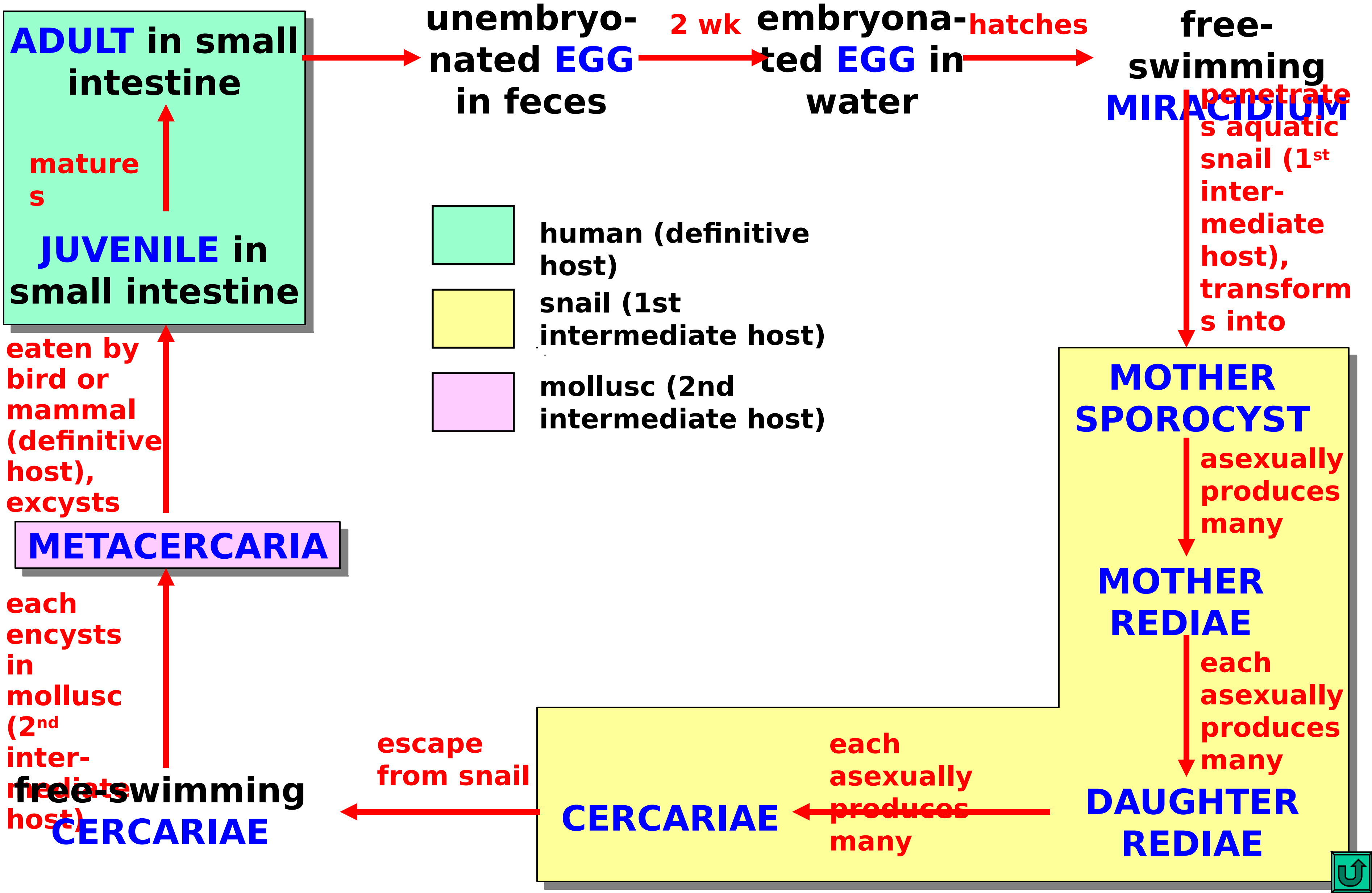

a
200 µm
b
50 µm

6.2

6.24 Eggs of *Schistosoma haematobium* in the wall of the urinary bladder. **a.** Large numbers of calcified eggs in the muscularis. Note the thickened epithelium. **b.** Higher magnification of eggs. The terminal spines of the eggs are not visible in this section. Damage to the bladder wall can lead to hematuria, bacterial infections, as well as metaplasia and possibly cancer of the bladder epithelium.



Life cycle of *Echinostoma revolutum*



ADULT in small intestine

unembryonated **EGG** in feces

2 wk

embryonated **EGG** in water

hatches

free-swimming **MIRACIDIUM**

penetrates aquatic snail (1st intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

MOTHER REDIAE

each asexually produces many

DAUGHTER REDIAE

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

each encysts in mollusc (2nd intermediate host)

METACERCARIA

eaten by bird or mammal (definitive host), excysts

JUVENILE in small intestine

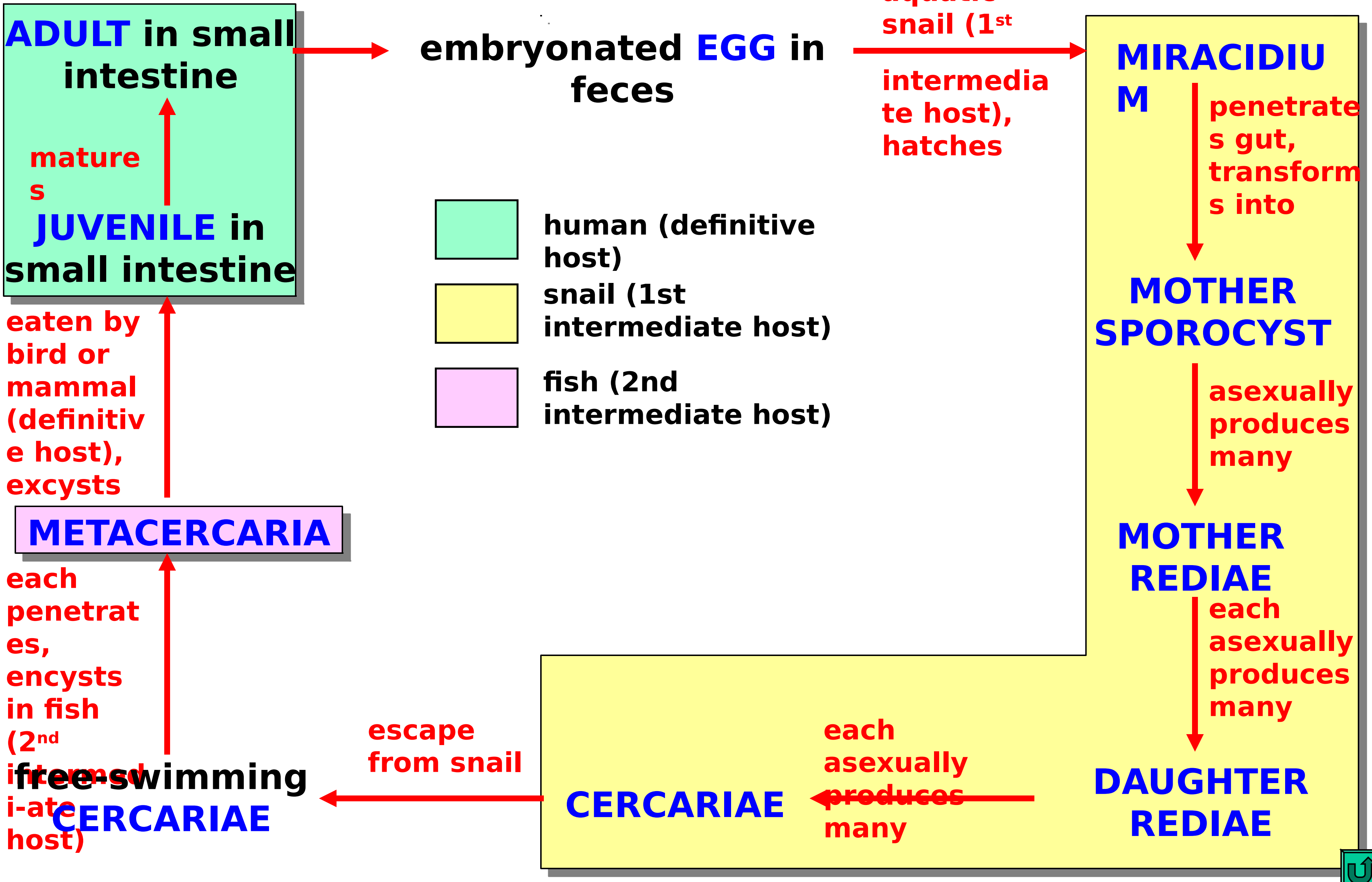
matures

🟩 human (definitive host)

🟨 snail (1st intermediate host)

🟪 mollusc (2nd intermediate host)

Life cycle of *Heterophyes heterophyes* & other heterophyids



ADULT in small intestine

mature s

JUVENILE in small intestine

embryonated **EGG** in feces

eaten by aquatic snail (1st intermediate host), hatches

MIRACIDIUM

penetrates gut, transforms into

MOTHER SPOROCYST

asexually produces many

MOTHER REDIAE

each asexually produces many

DAUGHTER REDIAE

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

each penetrates, encysts in fish (2nd intermed i-ate host)

METACERCARIA

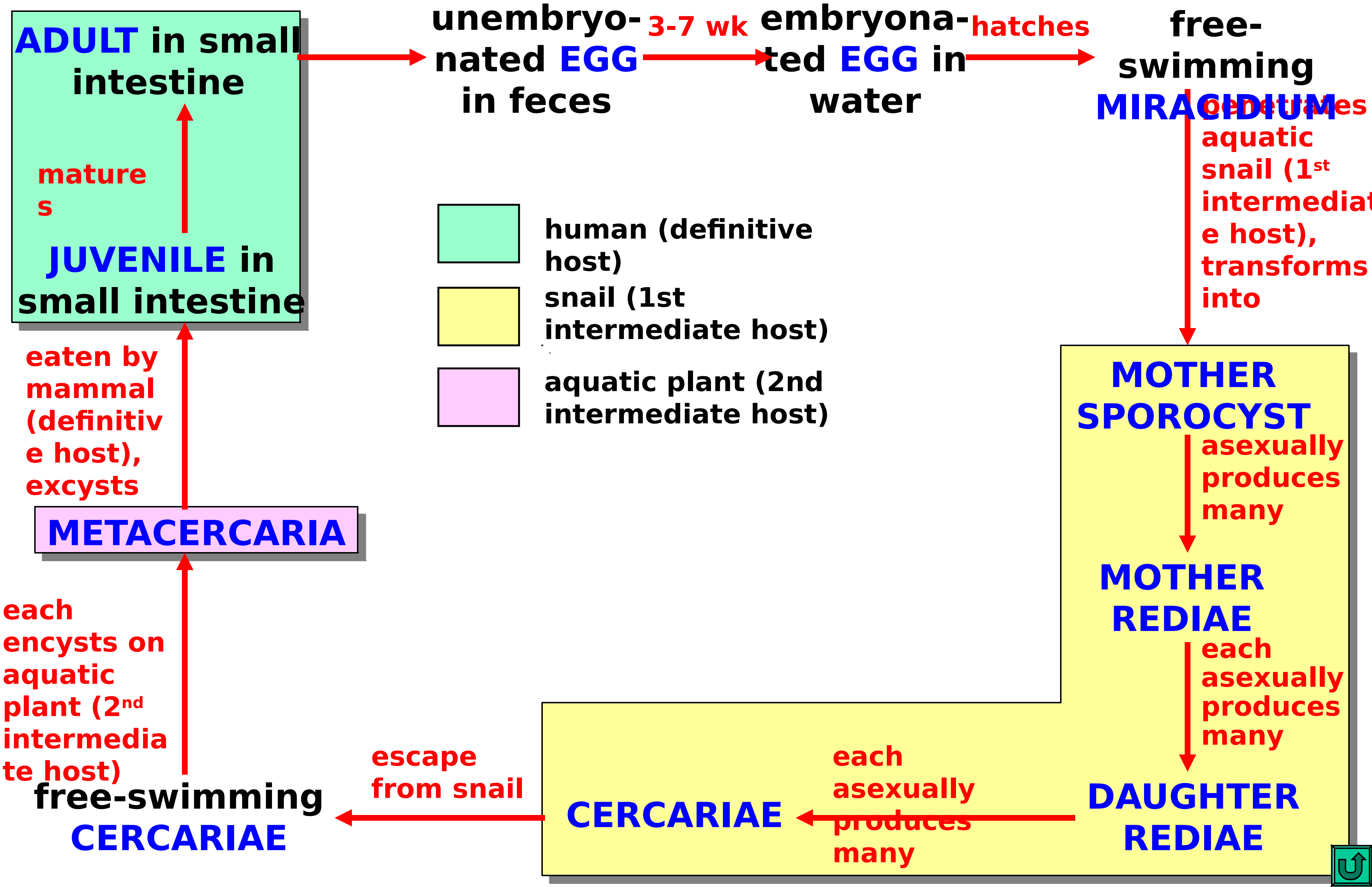
eaten by bird or mammal (definitive host), excysts

🟩 human (definitive host)

🟨 snail (1st intermediate host)

🟪 fish (2nd intermediate host)

Life cycle of *Fasciolopsis buski*



ADULT in small intestine

unembryonated **EGG** in feces

3-7 wk

embryonated **EGG** in water

hatches

free-swimming **MIRACIDIUM**

penetrates aquatic snail (1st intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

MOTHER REDIAE

each asexually produces many

DAUGHTER REDIAE

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

each encysts on aquatic plant (2nd intermediate host)

METACERCARIA

eaten by mammal (definitive host), excysts

JUVENILE in small intestine

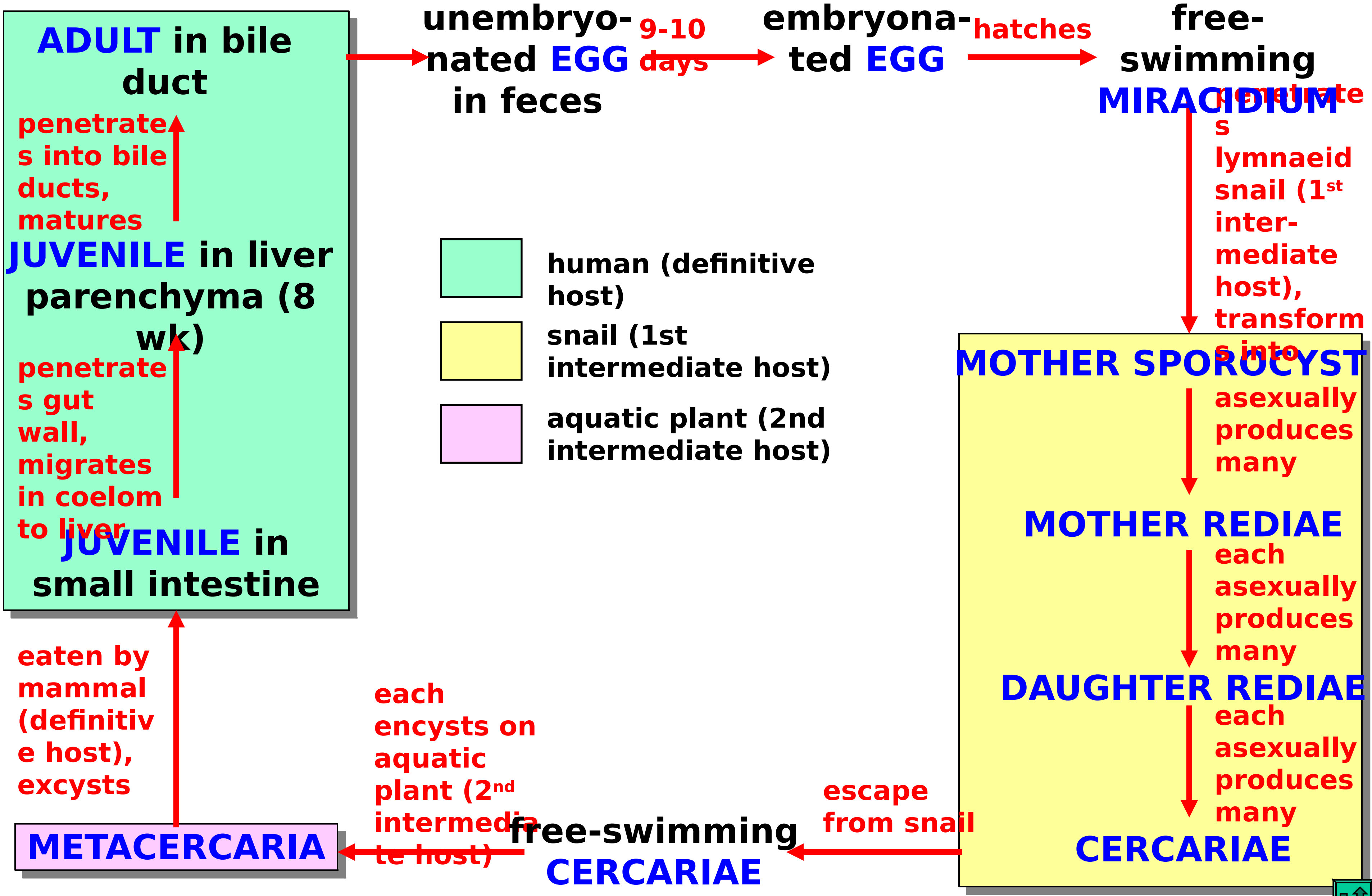
matures

🟩 human (definitive host)

🟨 snail (1st intermediate host)

🟪 aquatic plant (2nd intermediate host)

Life cycle of *Fasciola hepatica*



ADULT in bile duct

penetrates into bile ducts, matures

JUVENILE in liver parenchyma (8 wk)

penetrates gut wall, migrates in coelom to liver

JUVENILE in small intestine

unembryonated **EGG** in feces

9-10 days

embryonated **EGG**

hatches

free-swimming **MIRACIDIUM**

penetrates lymnaeid snail (1st intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

MOTHER REDIAE

each asexually produces many

DAUGHTER REDIAE

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

each encysts on aquatic plant (2nd intermediate host)

METACERCARIA

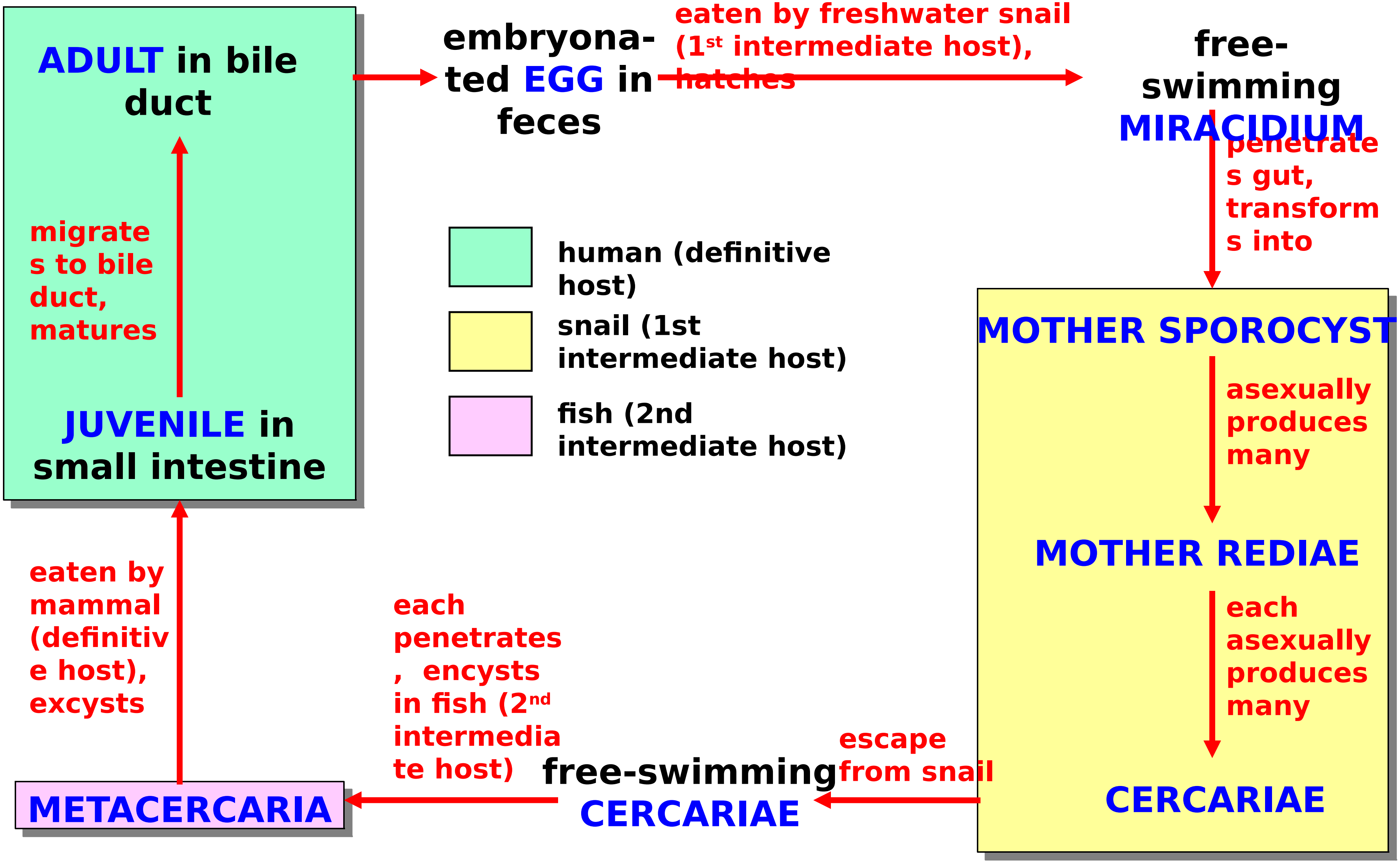
eaten by mammal (definitive host), excysts

🟩 human (definitive host)

🟨 snail (1st intermediate host)

🟪 aquatic plant (2nd intermediate host)

Life cycle of *Clonorchis sinensis*



ADULT in bile duct

embryonated **EGG** in feces

eaten by freshwater snail (1st intermediate host), hatches

free-swimming **MIRACIDIUM**

penetrates gut, transforms into

MOTHER SPOROCYST

asexually produces many

MOTHER REDIAE

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

each penetrates, encysts in fish (2nd intermediate host)

METACERCARIA

eaten by mammal (definitive host), excysts

JUVENILE in small intestine

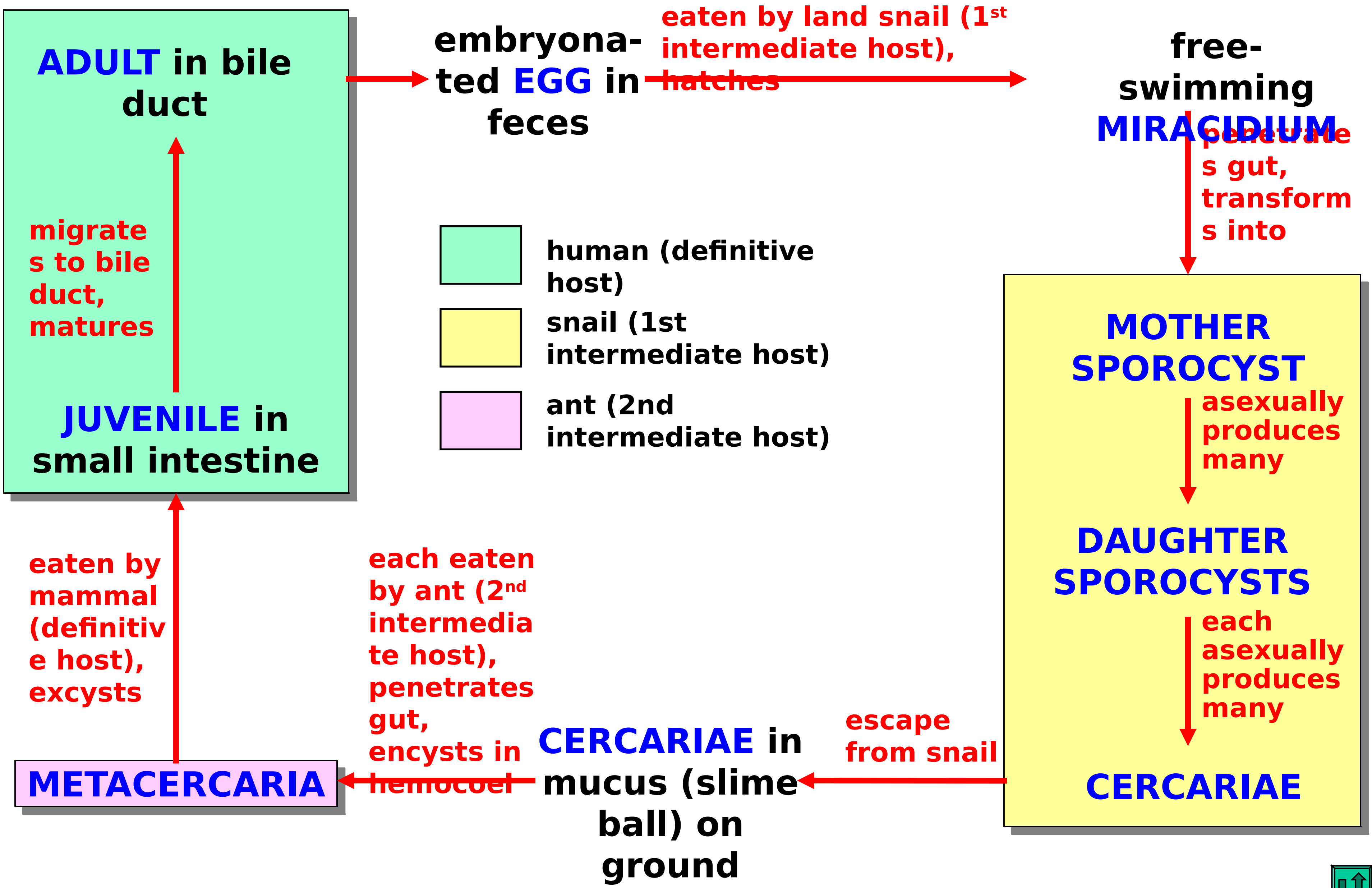
migrates to bile duct, matures

🟩 human (definitive host)

🟨 snail (1st intermediate host)

🟪 fish (2nd intermediate host)

Life cycle of *Dicrocoelium dendriticum*



ADULT in bile duct

embryonated **EGG** in feces

eaten by land snail (1st intermediate host), hatches

free-swimming **MIRACIDIUM**

penetrates gut, transforms into

MOTHER SPOROCYST

asexually produces many

DAUGHTER SPOROCYSTS

each asexually produces many

CERCARIAE

escape from snail

CERCARIAE in mucus (slime ball) on ground

each eaten by ant (2nd intermediate host), penetrates gut, encysts in hemocoel

METACERCARIA

eaten by mammal (definitive host), excysts

JUVENILE in small intestine

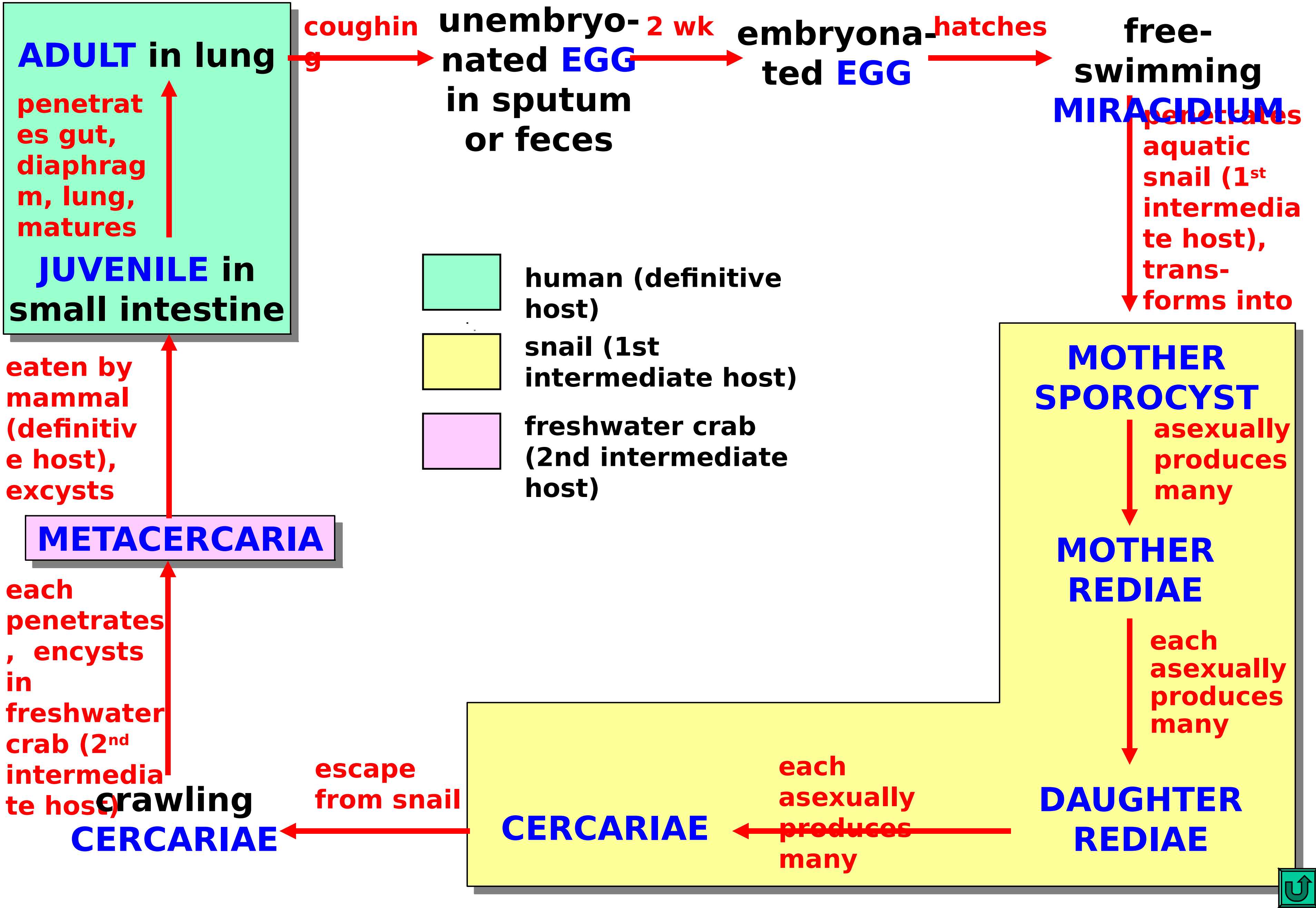
migrates to bile duct, matures

🟩 human (definitive host)

🟨 snail (1st intermediate host)

🟪 ant (2nd intermediate host)

Life cycle of *Paragonimus westermani*



ADULT in lung

coughing

unembryonated **EGG** in sputum or feces

2 wk

embryonated **EGG**

hatches

free-swimming **MIRACIDIUM**

penetrates aquatic snail (1st intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

MOTHER REDIAE

each asexually produces many

DAUGHTER REDIAE

each asexually produces many

CERCARIAE

escape from snail

crawling **CERCARIAE**

each penetrates, encysts in freshwater crab (2nd intermediate host)

METACERCARIA

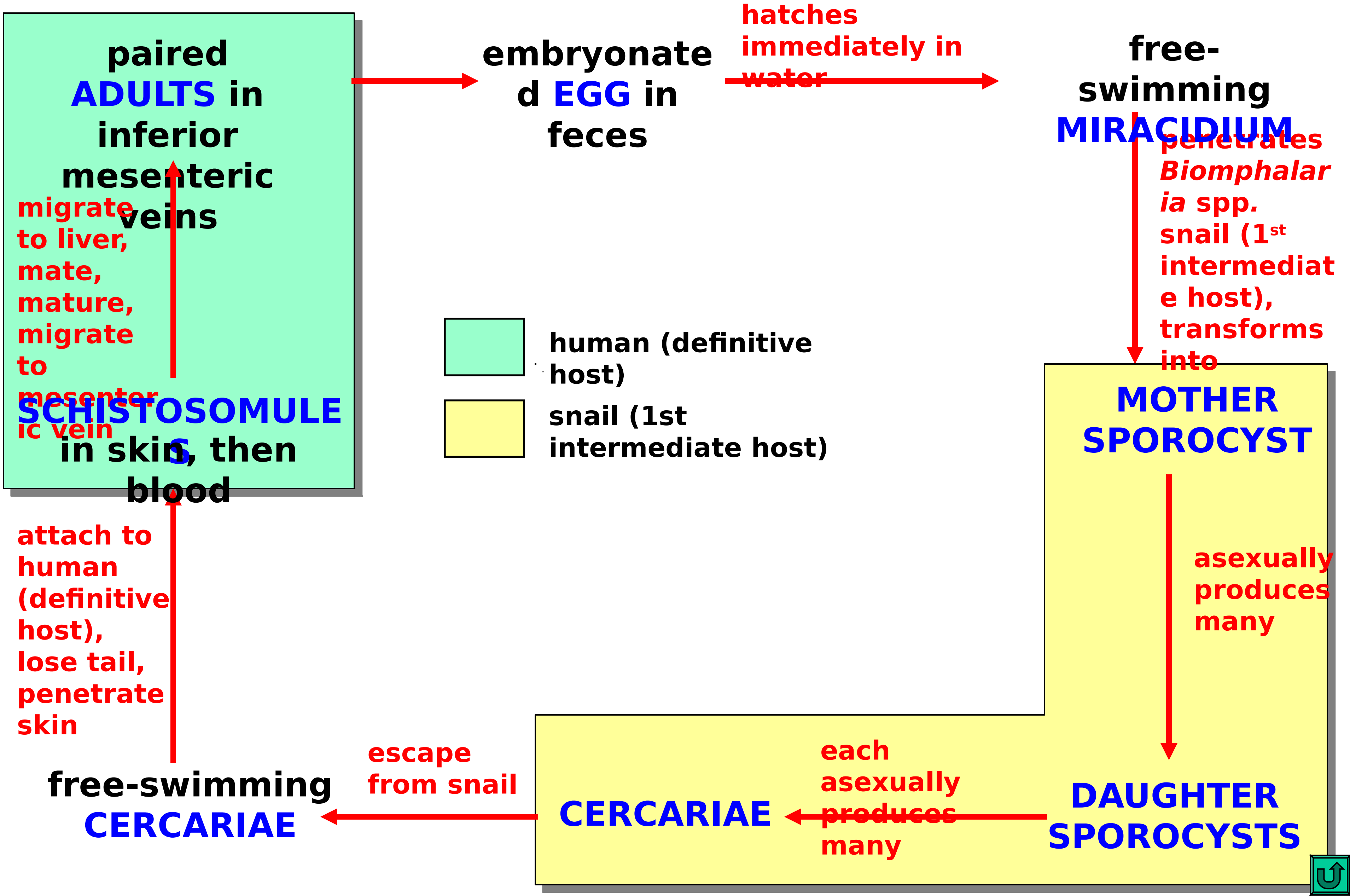
eaten by mammal (definitive host), excysts

JUVENILE in small intestine

penetrates gut, diaphragm, lung, matures

🟩 human (definitive host)
🟨 snail (1st intermediate host)
🟪 freshwater crab (2nd intermediate host)

Life cycle of *Schistosoma mansoni*



paired **ADULTS** in inferior mesenteric veins

embryonated **EGG** in feces

hatches immediately in water

free-swimming **MIRACIDIUM**

penetrates *Biomphalaria* spp. snail (1st intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

DAUGHTER SPOROCYSTS

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

attach to human (definitive host), lose tail, penetrate skin

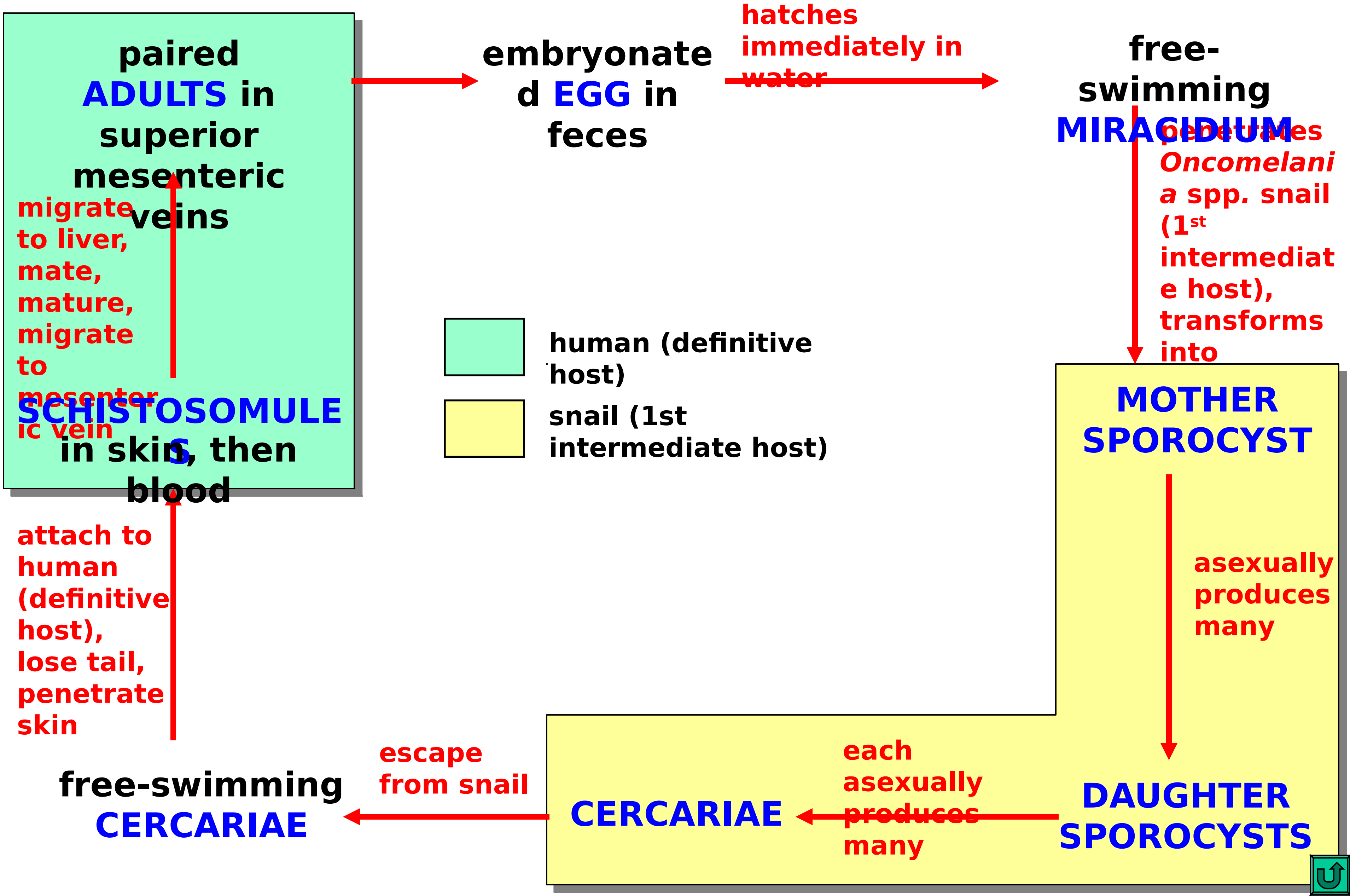
SCHISTOSOMULES in skin, then blood

migrate to liver, mate, mature, migrate to mesenteric vein

🟩 human (definitive host)

🟨 snail (1st intermediate host)

Life cycle of *Schistosoma japonicum*



paired **ADULTS** in superior mesenteric veins

embryonated **EGG** in feces

hatches immediately in water

free-swimming **MIRACIDIUM**

penetrates *Oncomelania* spp. snail (1^{st} intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

DAUGHTER SPOROCYSTS

each asexually produces many

CERCARIAE

escape from snail

free-swimming **CERCARIAE**

attach to human (definitive host), lose tail, penetrate skin

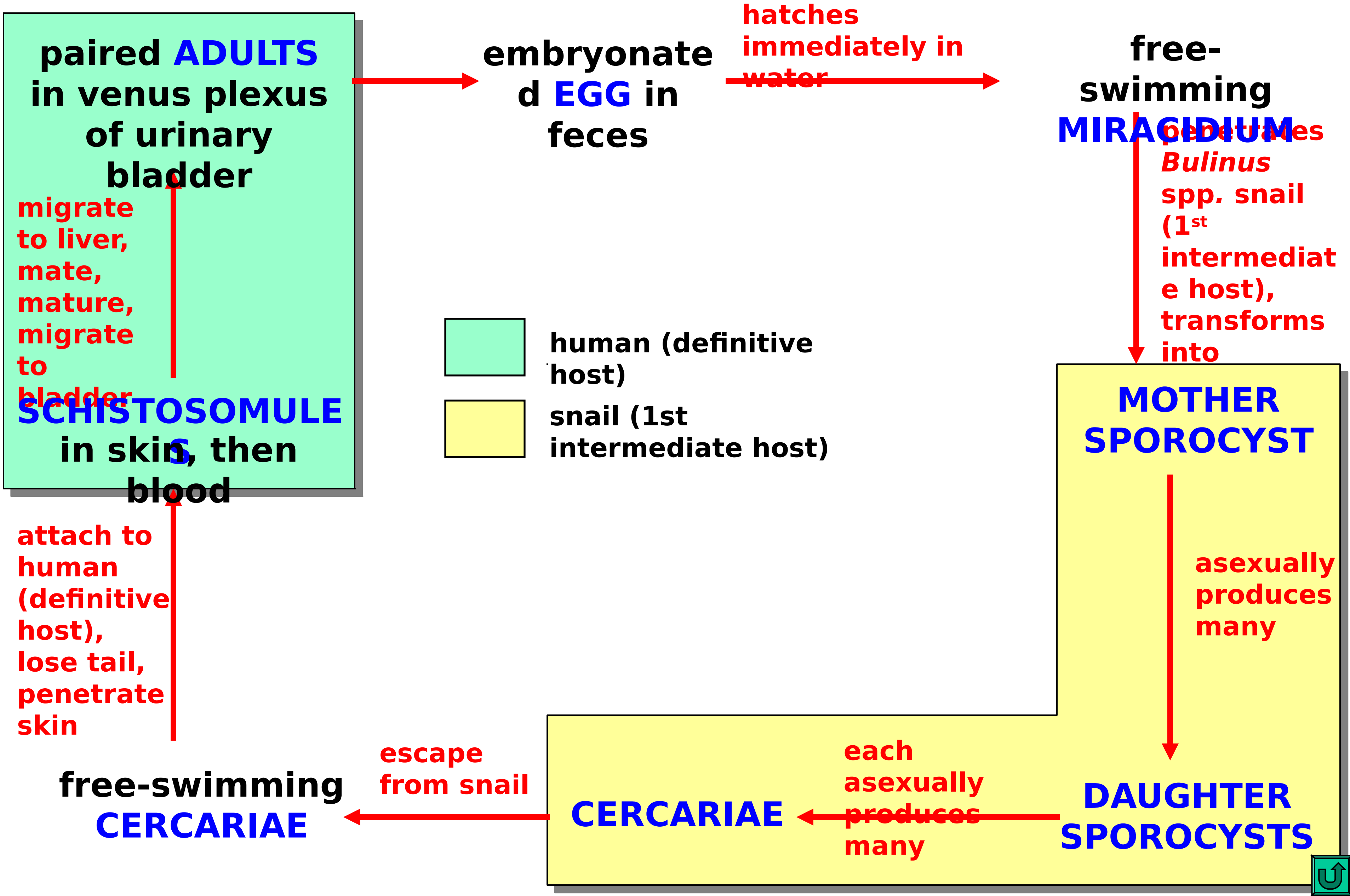
SCHISTOSOMULES in skin, then blood

migrate to liver, mate, mature, migrate to mesenteric vein

🟩 human (definitive host)

🟨 snail (1st intermediate host)

Life cycle of *Schistosoma haematobium*



paired ADULTS in venus plexus of urinary bladder

embryonated EGG in feces

hatches immediately in water

free-swimming MIRACIDIUM

penetrates *Bulinus* spp. snail (1st intermediate host), transforms into

MOTHER SPOROCYST

asexually produces many

DAUGHTER SPOROCYSTS

each asexually produces many

CERCARIAE

escape from snail

free-swimming CERCARIAE

attach to human (definitive host), lose tail, penetrate skin

SCHISTOSOMULES in skin, then blood

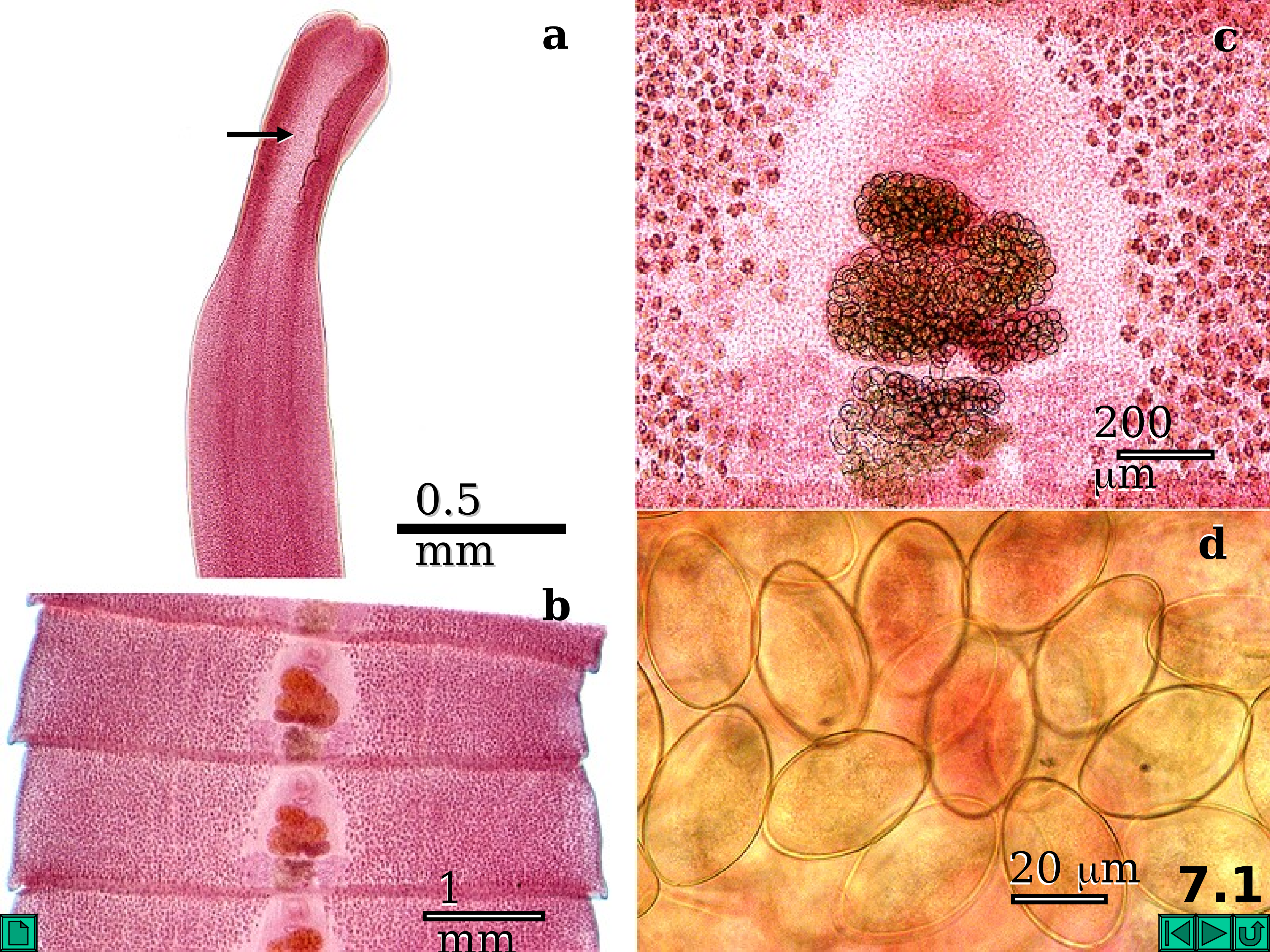
migrate to liver, mate, mature, migrate to bladder

🟩 **human (definitive host)**

🟨 **snail (1st intermediate host)**

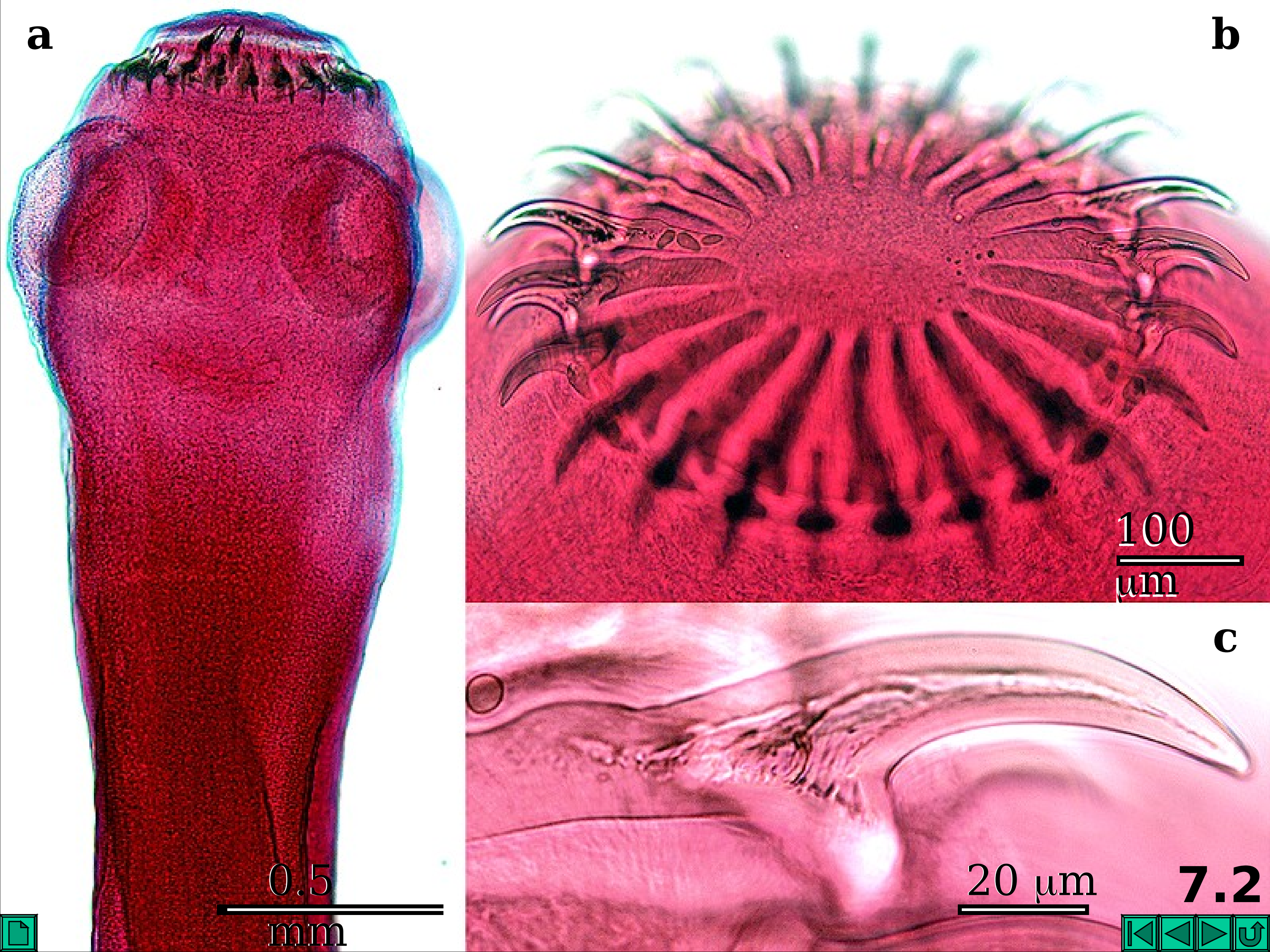
7. Cestodes (Tapeworms)

- *Diphyllobothrium latum*
- Scolex of *Taenia pisiformis*
- Proglottids of *Taenia pisiformis*
- *Taenia saginata* vs. *Taenia solium*
- Cysticercus of *Taenia solium*
- *Echinococcus granulosus*
- Unilocular hydatid cyst
- Multilocular hydatid cyst
- *Hymenolepis nana*
- *Hymenolepis diminuta*
- *Dipylidium caninum*
- Eggs of *Diphyllobothrium latum*
- Eggs of *Hymenolepis nana*
- Eggs of *Hymenolepis diminuta*
- Taeniid eggs
- Eggs of *Dipylidium caninum*


a
0.5 mm
b
1 mm
c
200 µm
d
20 µm

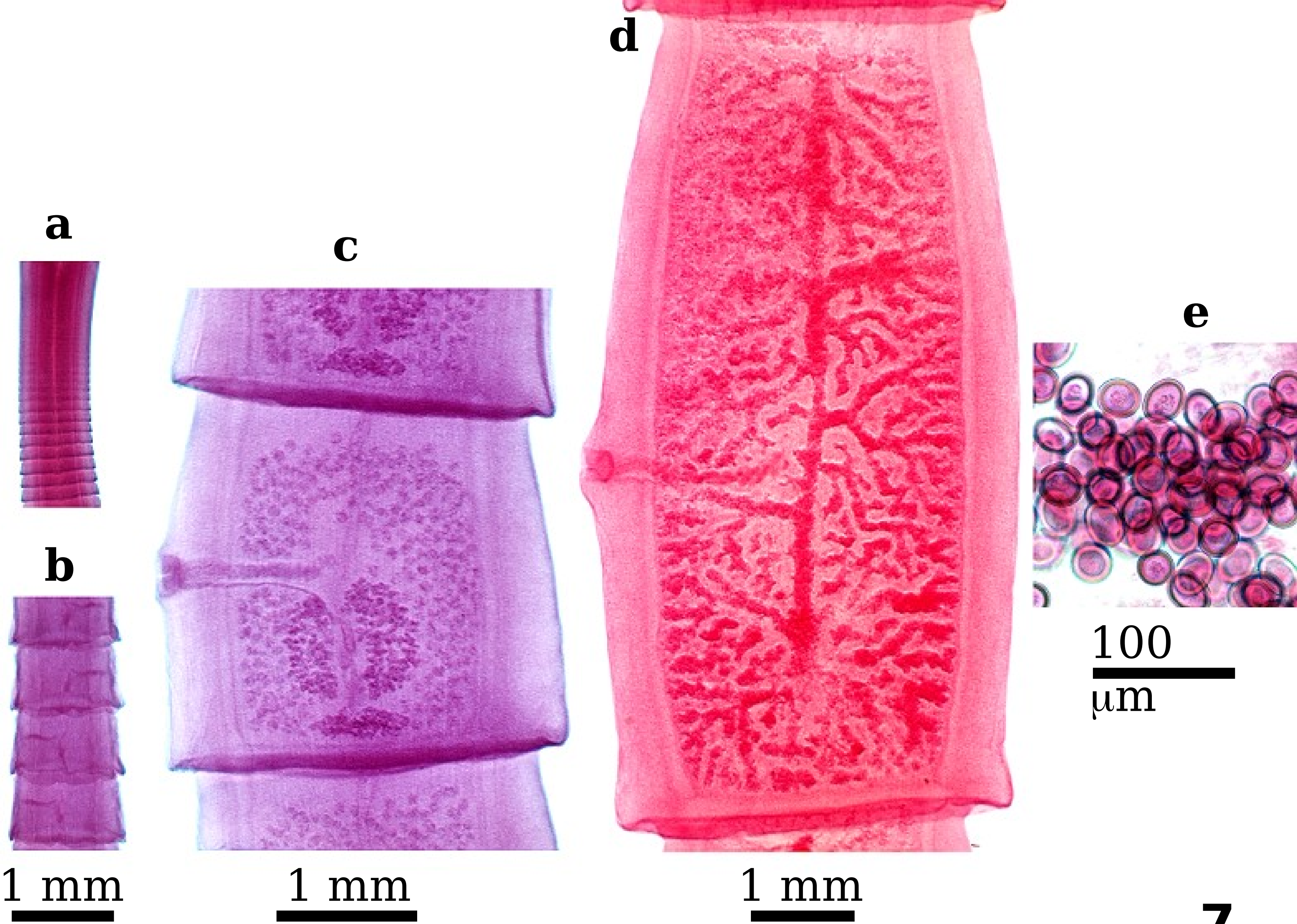
7.1

7.1 Adult of *Diphyllobothrium latum*. **a.** Scolex, showing groove-like bothrium (arrow) used to grasp the host mucosa. **b.** Gravid proglottid. **c.** Higher magnification of gravid proglottid, showing bilobed ovary, uterus with eggs, and follicular vitelline glands. The minute pink dots visible in the center of the proglottid are follicular testes, which are situated between the dorsal and ventral layers of vitelline follicles. In this species, eggs are released through the uterine pore, located anterior to the uterus. For a labeled photo of the proglottid, click here. **d.** Higher magnification of eggs in uterus. Infection results from eating second intermediate or paratenic hosts infected with plerocercoids. Symptoms range from none to fatigue, to diarrhea; however, approximately 2% of infected individuals develop megaloblastic anemia, due to the worm's unique affinity for vitamin B_{12}. Ingestion of first intermediate hosts (or of intermediate or parate


a
b
c
0.5 mm
100 µm
20 µm

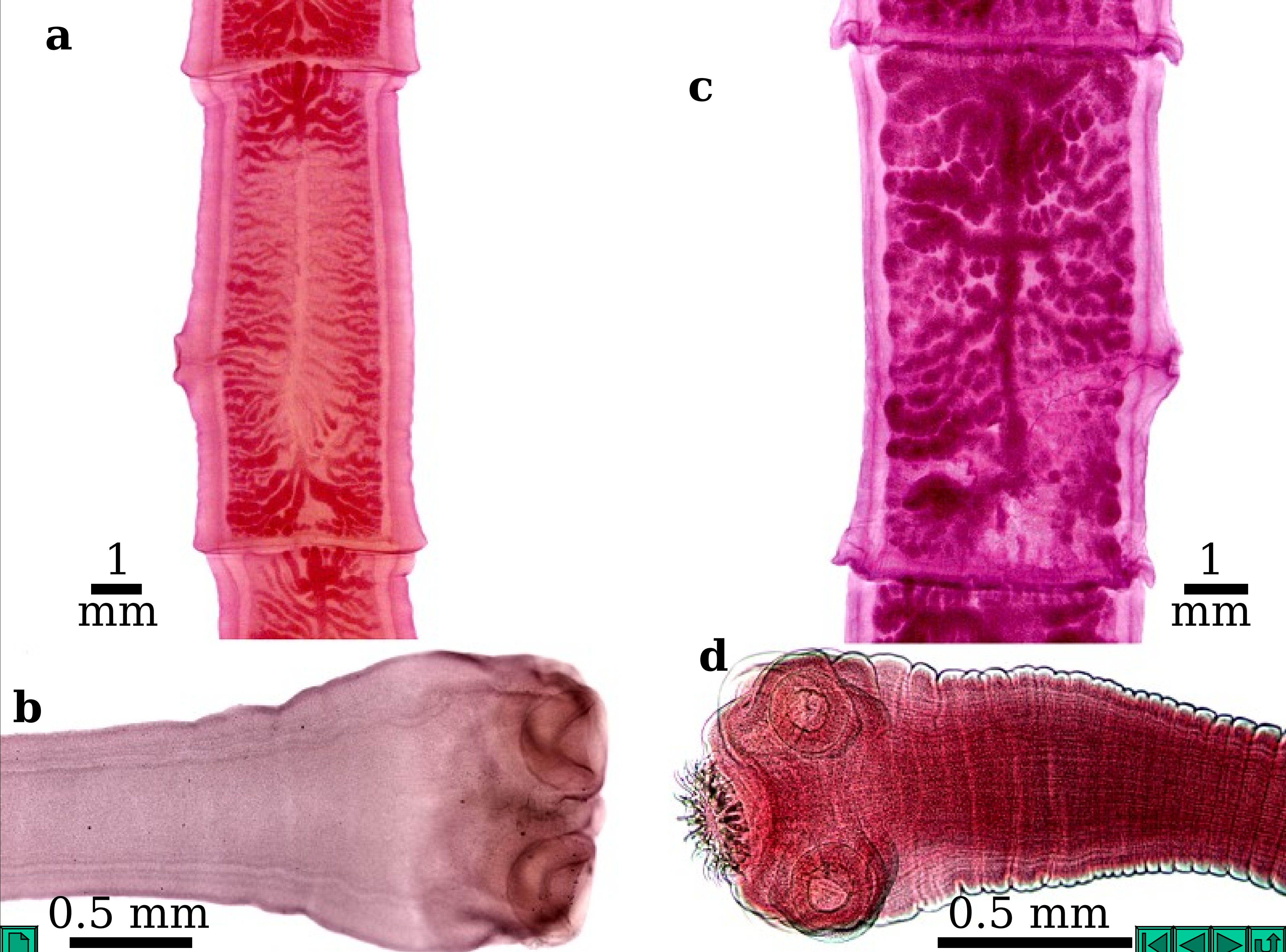
7.2

7.2 Scolex of *Taenia pisiformis*, a tapeworm of dogs, that shows typical cyclophyllidean anatomy. **a.** Scolex and neck (where immature proglottids are formed), showing armed rostellum and 4 acetabula (suckers). The scolex of *T. solium* would appear similar, whereas that of *T. saginata* lacks hooks. **b.** Higher magnification of rostellum, showing circle of hooks. **c.** Higher magnification of individual hook.


a
b
c
d
e
1 mm
1 mm
1 mm
100 µm

7.

7.3 Strobila (body) of *Taenia pisiformis,* combined from several specimens. **a.** Immature proglottids being formed from neck region. **b.** Immature proglottids containing developing reproductive organs. **c.** Mature proglottid, showing a bilobed ovary, follicular testes, lateral genital pore, and posterior vitelline mass. Ventral canals of the excretory system are visible laterally. For a labeled photo of the proglottid, click here. **d.** Gravid proglottid, in which the uterus has developed side branches filled with eggs. **e.** Higher magnification of a uterine branch, showing eggs.

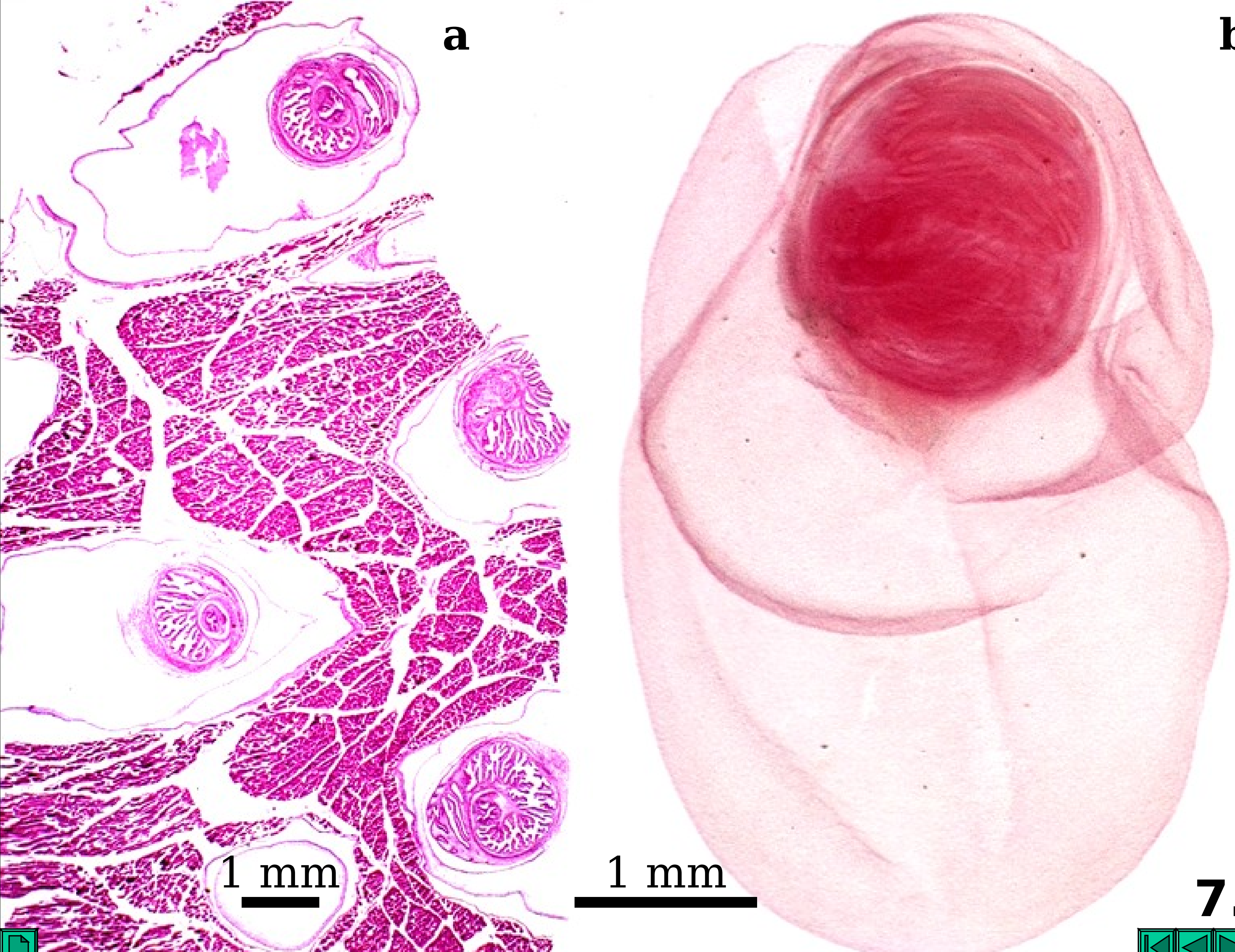

a
1 mm
c
1 mm
b
0.5 mm
d
0.5 mm

7.4 *Taenia saginata* vs. *T. solium*. **a.** Proglottid of *T. saginata*. **b.** Scolex of *T. saginata*. Note the absence of hooks. **c.** Proglottid of *T. solium*. **d.** Scolex of *T. solium*. Note the rostellum, armed with hooks. The two species can be distinguished both on the basis of their scolex, and by counting the number of primary side branches of the gravid uterus, numbering >14 in *T. saginata* and <14 in *T. solium*. Human infections with the adult worm are acquired by eating undercooked beef (*T. saginata*) or pork (*T. solium*) infected with cysticerci. Infections with adults usually cause mild or no symptoms. However, *T. solium* is quite hazardous, because its eggs (unlike those of *T. saginata*), if ingested by humans, release an oncosphere that develops into a bladder-like cysticercus larva, which can cause severe disease in the brain or eye. Also, gravid proglottids may rupture in the intestinal lumen, releasing thousa
of i ctive eggs, resulting in overwhelming

- back to scolex of *Taenia pisiformis*

T.
nata

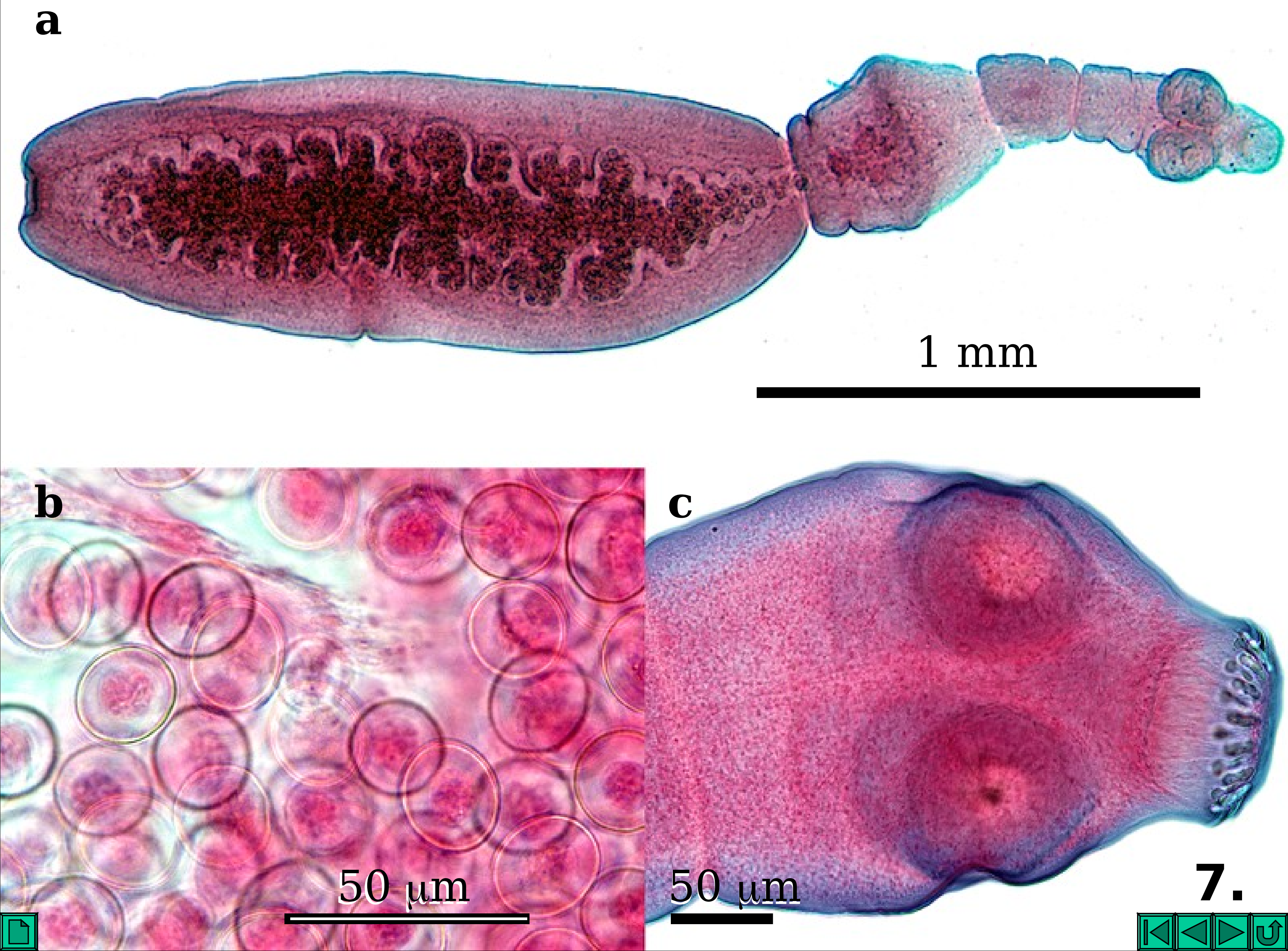
T. solium



7.

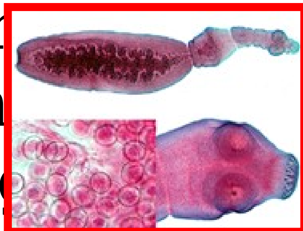
7.5 Cysticercus of *Taenia solium*. **a.** Histological section of infected pork, showing 4 cysticerci, each consisting of a fluid-filled bladder containing an invaginated, introverted (inside-out) scolex. Cysticercosis results from ingestion of *T. solium* eggs from human feces, and occurs in both pigs and humans. Also, humans harboring the adult tapeworm may develop heavy burdens of cysticerci when gravid proglottids are retained in the intestine and then rupture, releasing thousands of infective eggs. Cysticerci can lodge in any organ, and may be visible as surface swellings if occurring subcutaneously. Depending on numbers and location, cysticerci in the brain may cause symptoms of epilepsy. Note the absence of inflammation around viable cysticerci. Howev dead cysticerci elicit a strong inflammatory response, which can be fatal if occurring in th

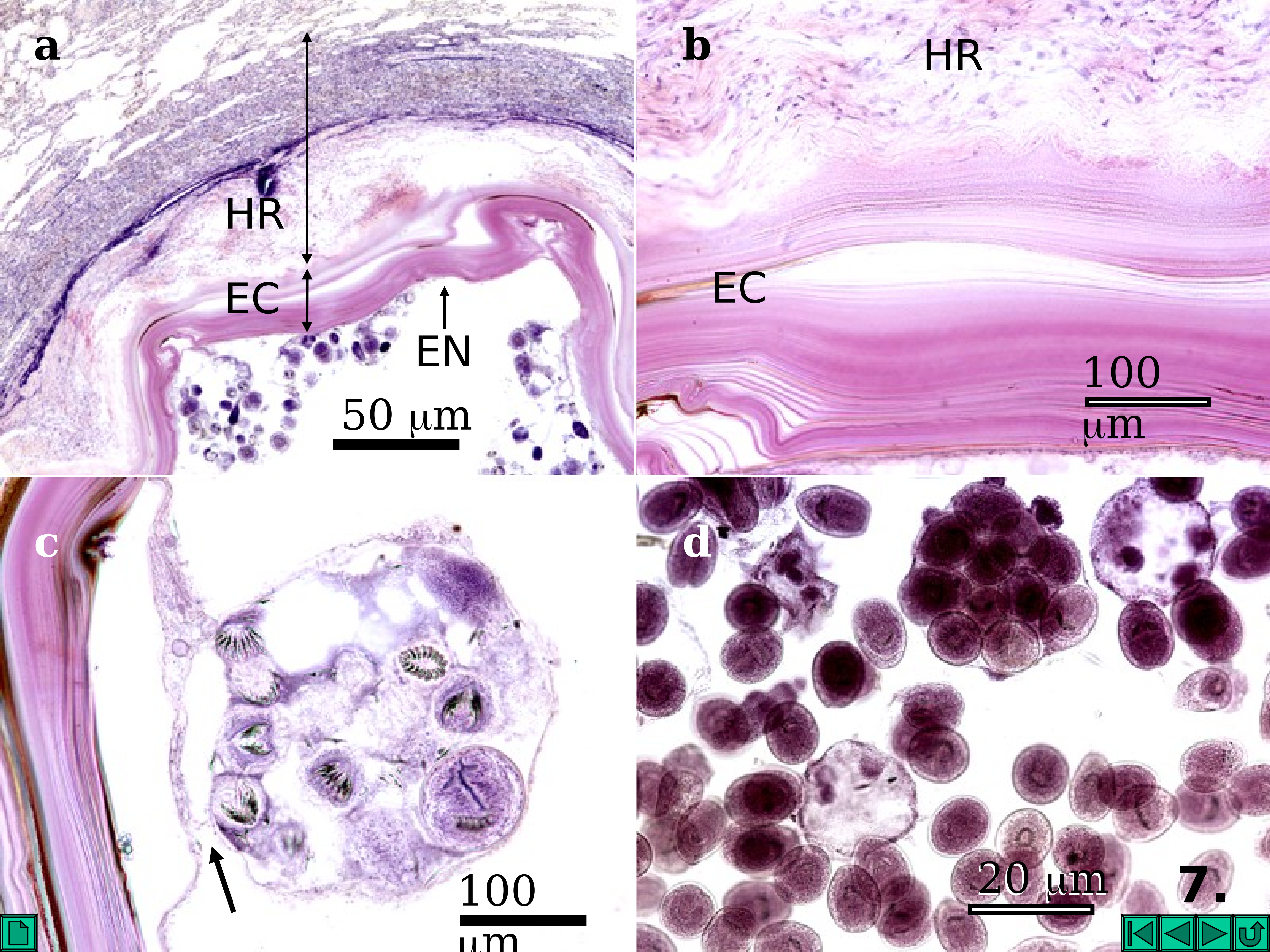
- back to adult of *T. solium* and *T. saginata*


a
1 mm
b
50 µm
c
50 µm

7.

7.6 Adult of *Echinococcus granulosus*. **a.** Adult worm, consisting of a scolex and 3 proglottids. **b.** Eggs in uterus. These are indistinguishable from eggs of other taeniids. **c.** Higher magnification of the scolex (different specimen than in **a.**), which bears 4 suckers and an armed rostellum. When eggs of this parasite are ingested by intermediate hosts, including humans, the oncosphere develops in internal organs into a large fluid-filled hydatid cyst, in which infectious protoscolices are produced asexually. These cysts grow slowly, sometimes filling with up to 2 liters of fluid, eventually compressing surrounding tissues. Disease may result from pressure effects or from rupture of large cysts, causing anaphylactic shock. This parasite is more common in sheep-rearin areas, where sheep, rabbits, and other mamm eaten by dogs become infected by ingesting e

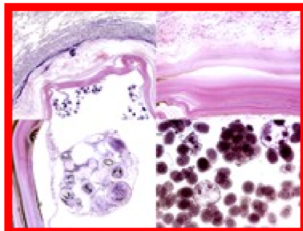


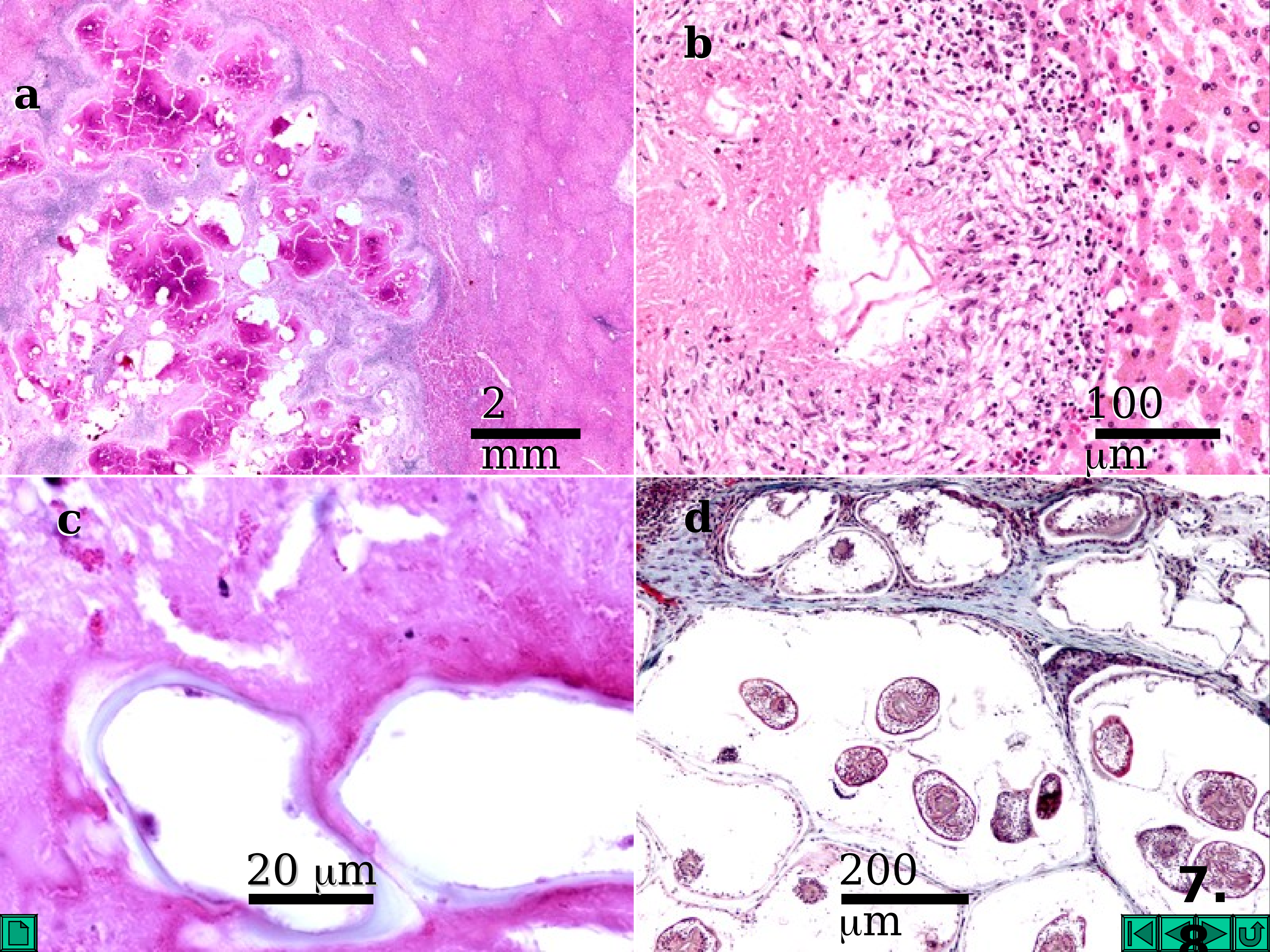

a
HR
EC
EN
50 µm
b
HR
EC
100 µm
c
100 µm
d
20 µm

7.

7.7 Unilocular hydatid cyst of *Echinococcus granulosus*. This cyst develops in the internal organs of intermediate hosts, including humans, that ingest eggs from feces of infected canids. **a.** Histological section of the wall of a unilocular cyst. Hanging into the fluid filled cavity are brood capsules, composed of germinal membrane and containing protoscolices. The inner germinal layer of the cyst (endocyst, EN) is surrounded by an acellular, laminated ectocyst (EC). A thick fibrous tissue host response (HR) surrounds the ectocyst. **b.** Higher magnification of the laminated ectocyst. **c.** A single brood capsule, attached to the germinal epithelium endocyst by a stalk or pedicel (arrow). The outer margin of the brood capsule consists of germinal epithelium. Several protoscolices, bearing hooks, are visible. **d.** Hydatid sand. The granular material that

- back to adult of *Echinococcus granulosus*

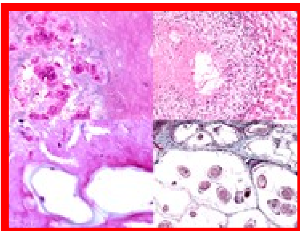


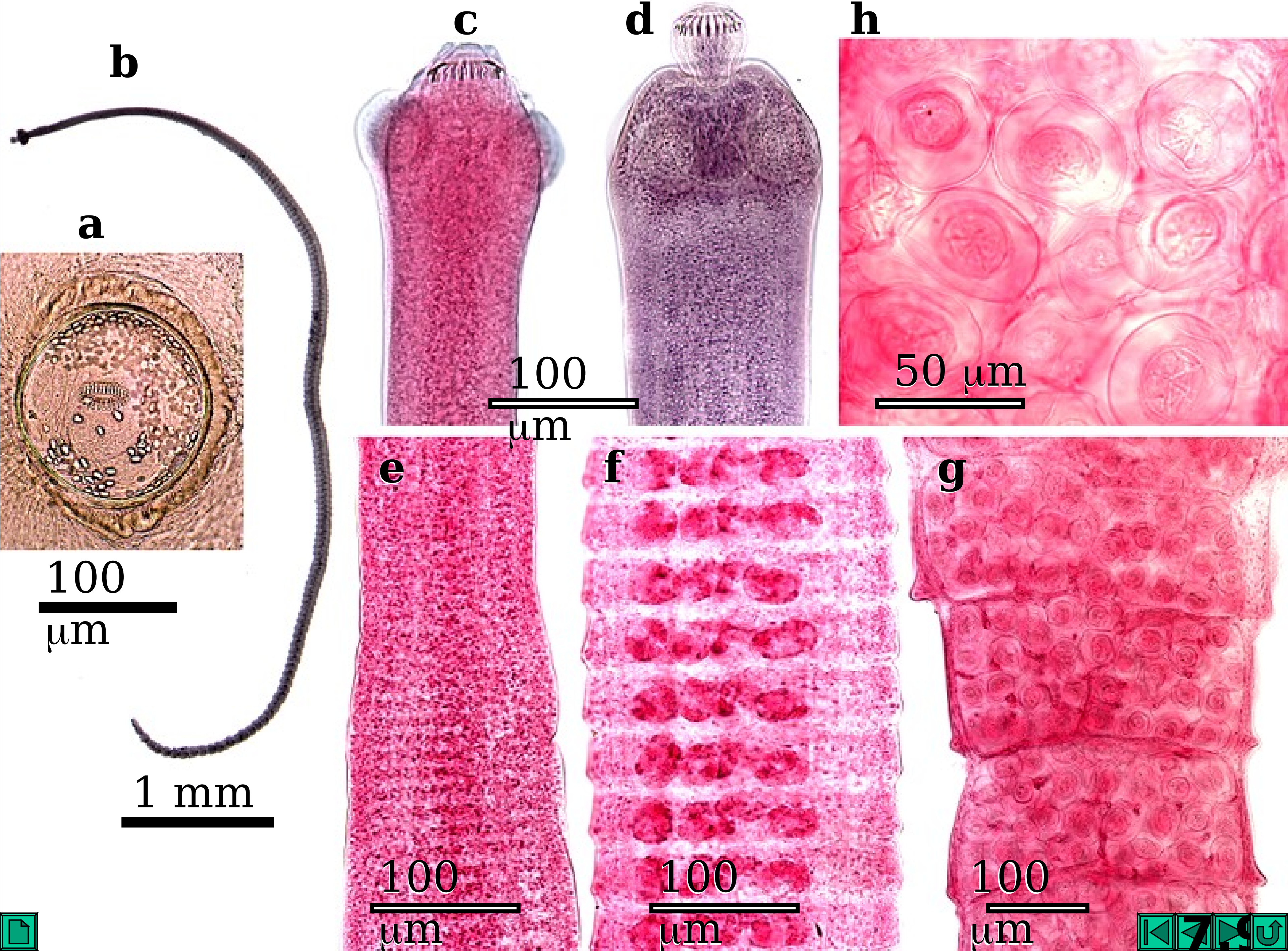

a
2 mm
b
100 µm
c
20 µm
d
200 µm

7.8

7.8. Multilocular (alveolar) hydatid cyst of *Echinococcus multilocularis*. This cyst develops in the internal organs of intermediate hosts, including humans, that ingest eggs from feces of infected canids. *E. multilocularis* is mainly a parasite of wild canids, especially foxes, and consequently fur trappers are at risk of infection. **a.** Portion of multilocular cyst from human liver. Humans are physiologically unsuitable hosts, and as a result protoscolices are not formed. Instead, the cyst fills with eosinophilic necrotic material. Note the invasion of liver tissue at the periphery of the cyst. **b.** Higher magnification of outward-growing periphery of the cyst. **c.** Higher magnification of ectocyst (hyaline layer). Because the cyst of this species lacks a restraining laminated ectocyst, the germinal membrane can grow outward into surrounding tissues or break off and metastasiz

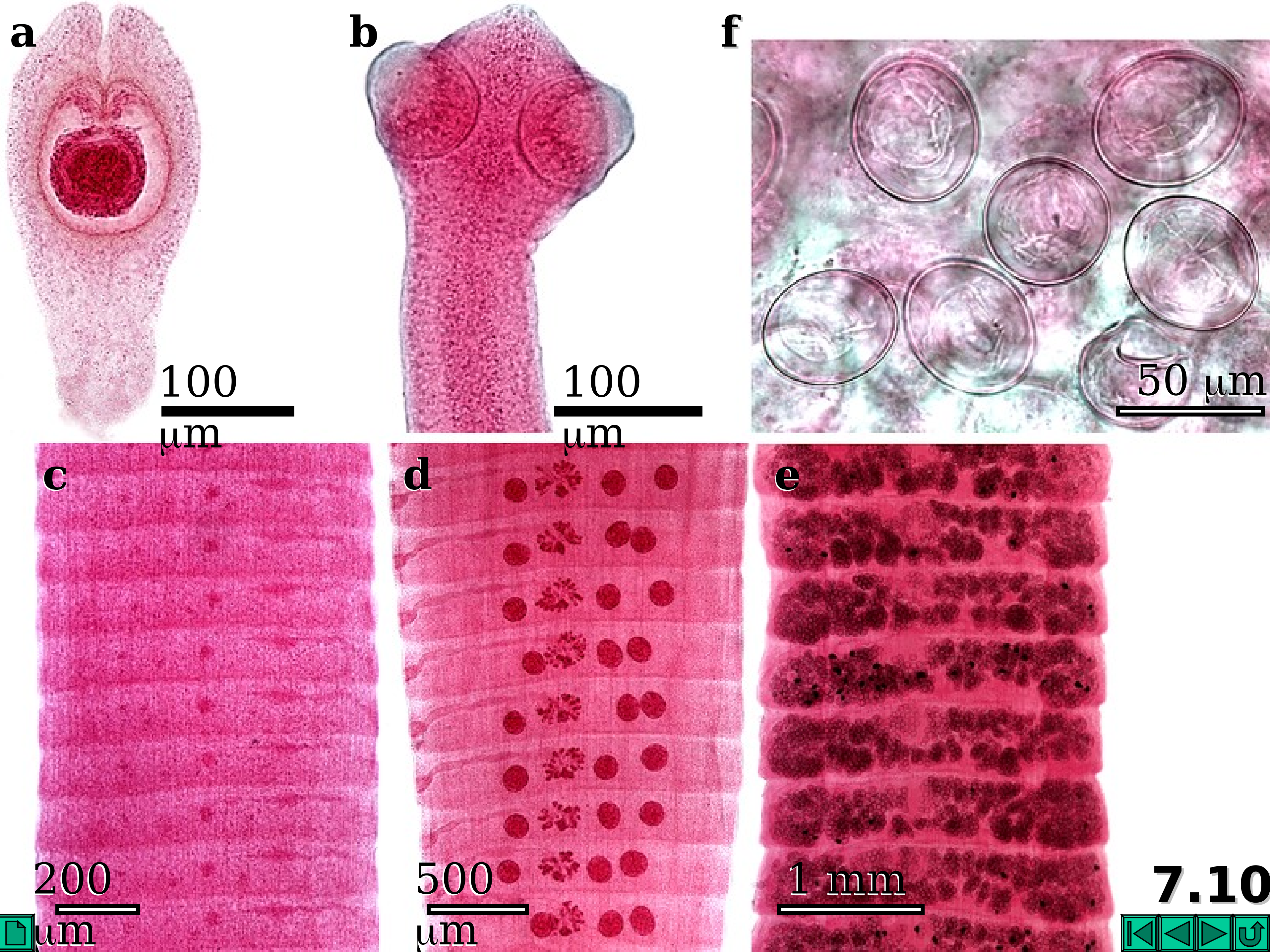
other sites. Therefore, prognosis is grave unles




a
100 µm
b
1 mm
c
d
100 µm
h
50 µm
e
100 µm
f
100 µm
g
100 µm

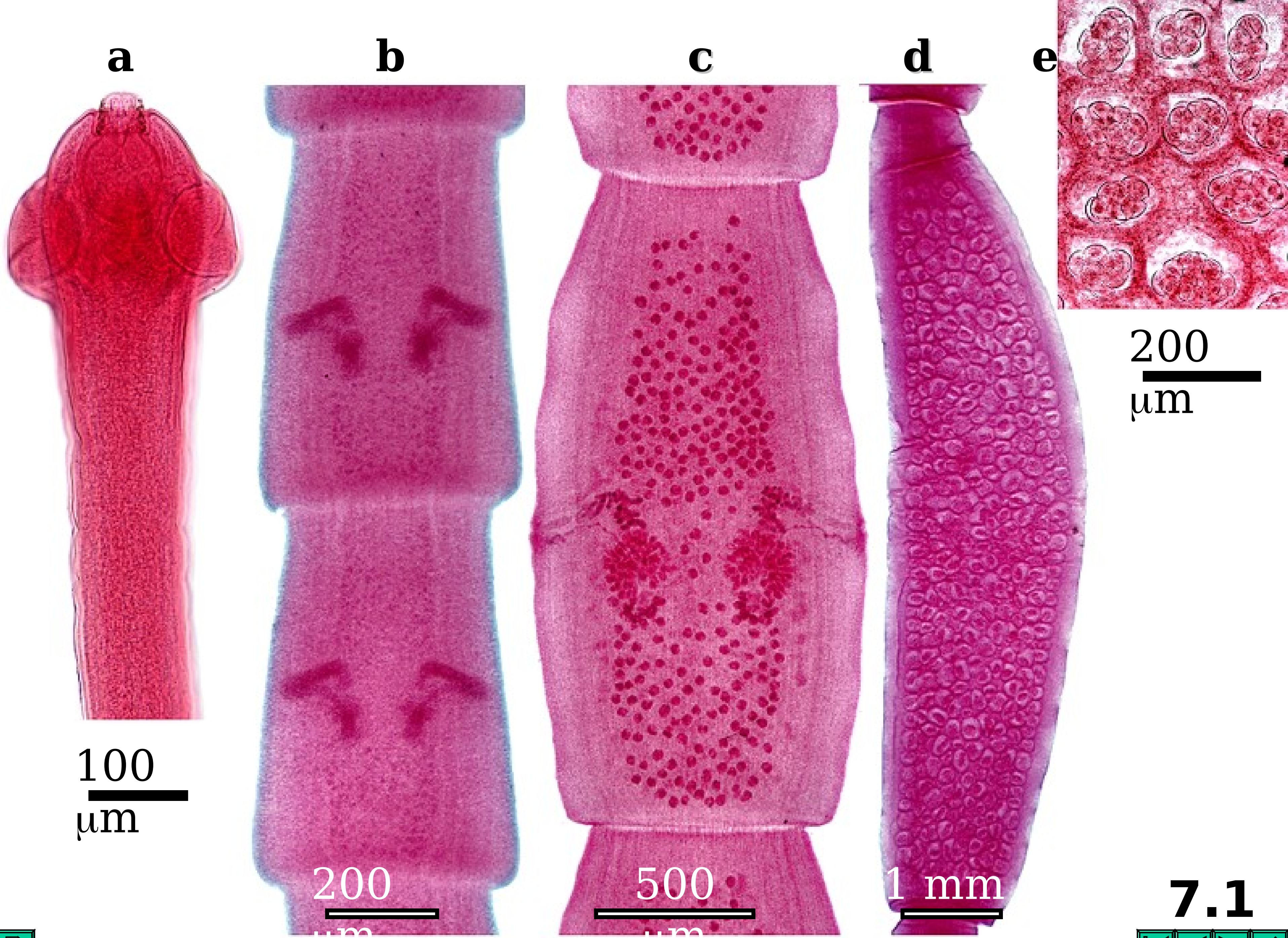
7.9 *Hymenolepis nana*. **a.** Anterior end of cysticercoid in a squash of a grain beetle. Note the circle of hooks. **b.** Adult. **c.** Scolex with retracted rostellum. **d.** Scolex with extended rostellum. **e.** Immature proglottids. **f.** Mature proglottids, showing 3 oval testes. For a labeled photo of a proglottid, click here. **g.** Gravid proglottids. **h.** Eggs in the uterus. This species is unique among tapeworms in not requiring an intermediate host to complete its life cycle (a direct or homoxenous life cycle). However, an indirect life cycle, utilizing an insect intermediate host, also can occur. Humans become infected by ingesting eggs from rodent or human feces, or by ingesting intermediate hosts infected with cysticercoids. Light infections are asymptomatic. However, because eggs may hatch in the intestine of the definitive host, autoinfection can produ heavy infections (thousands of worms), leadin humans to diarrhea and toxicity.

- back to adult of *Hymenolepis diminuta*


a
100 µm
b
100 µm
f
50 µm
c
200 µm
d
500 µm
e
1 mm

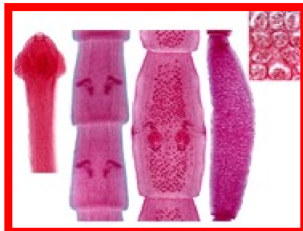
7.10

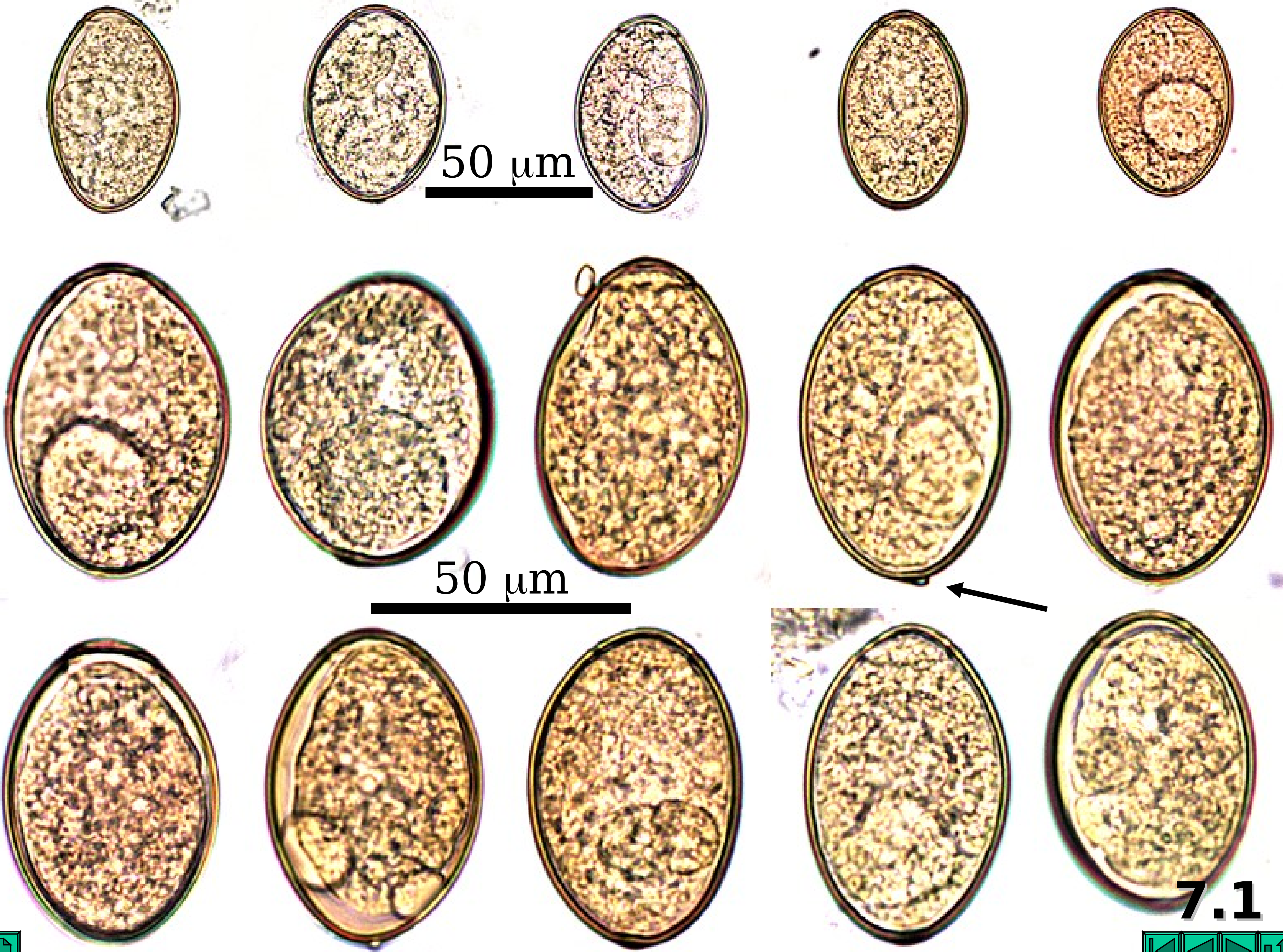
7.10 *Hymenolepis diminuta*. **a.** Cysticercoid. **b.** Scolex with retracted, unarmed rostellum. **c.** Immature proglottids. **d.** Mature proglottids, showing 3 oval testes and a single ovary. For a labeled photo of a proglottid, click here. **e.** Gravid proglottids. **f.** Eggs in the uterus. This species requires an insect intermediate host, in which the cysticercoid develops. Because its eggs are not infective for the definitive host, human infections with *H. diminuta* are less prevalent than those with *H. nana*, and are usually light and asymptomatic.


a
b
c
d
e
100 µm
200 µm
500 µm
1 mm
200 µm

7.1

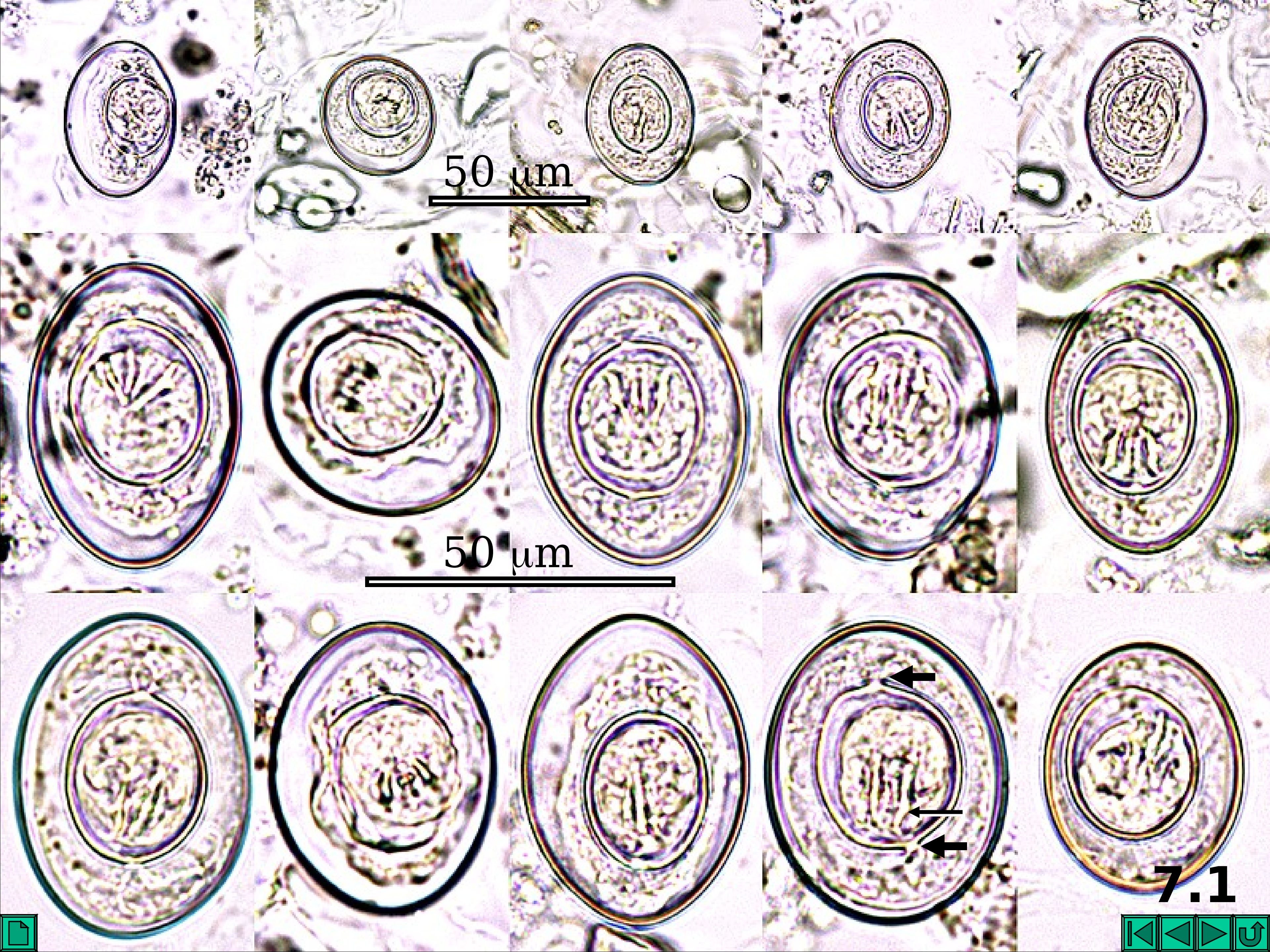
7.11 *Dipylidium caninum*. **a.** Scolex, consisting of 4 suckers and an armed rostellum, partially retracted into a sac in this photograph. **b.** Immature proglottid. **c.** Mature proglottid. Note the two lateral genital pores, diagnostic for this species. For a labeled photo of the proglottid, click here. **d.** Gravid proglottid, in which the uterus has broken up into egg capsules, each containing 5-20 eggs. Gravid proglottids are quite motile for a short time after being passed out in the feces. **e.** Egg capsules in the uterus. This relatively harmless tapeworm is a cosmopolitan parasite of dogs and cats, and rarely humans, most often children. Infections are acquired by ingesting a flea intermediate host infected with the cysticercoid stage.




50 µm
50 µm

7.12 Eggs of *Diphyllobothrium latum*. Because of the large size of the adult, a million eggs/day may be shed in the feces from each worm. The eggs are operculate, symmetrically oval, and sometimes have an abopercular knob (arrow). Structurally they are similar to a trematode egg. The embryo is undeveloped when the egg is released from the uterus, and must complete its development to the coracidium stage (a ciliated oncosphere) in fresh water. Top row is at same magnification as trematode eggs in the previous chapter.

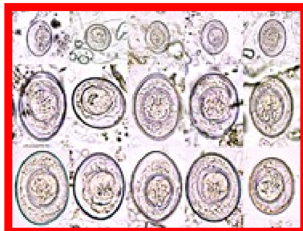
- back to adults of *Diphyllobothrium latum*

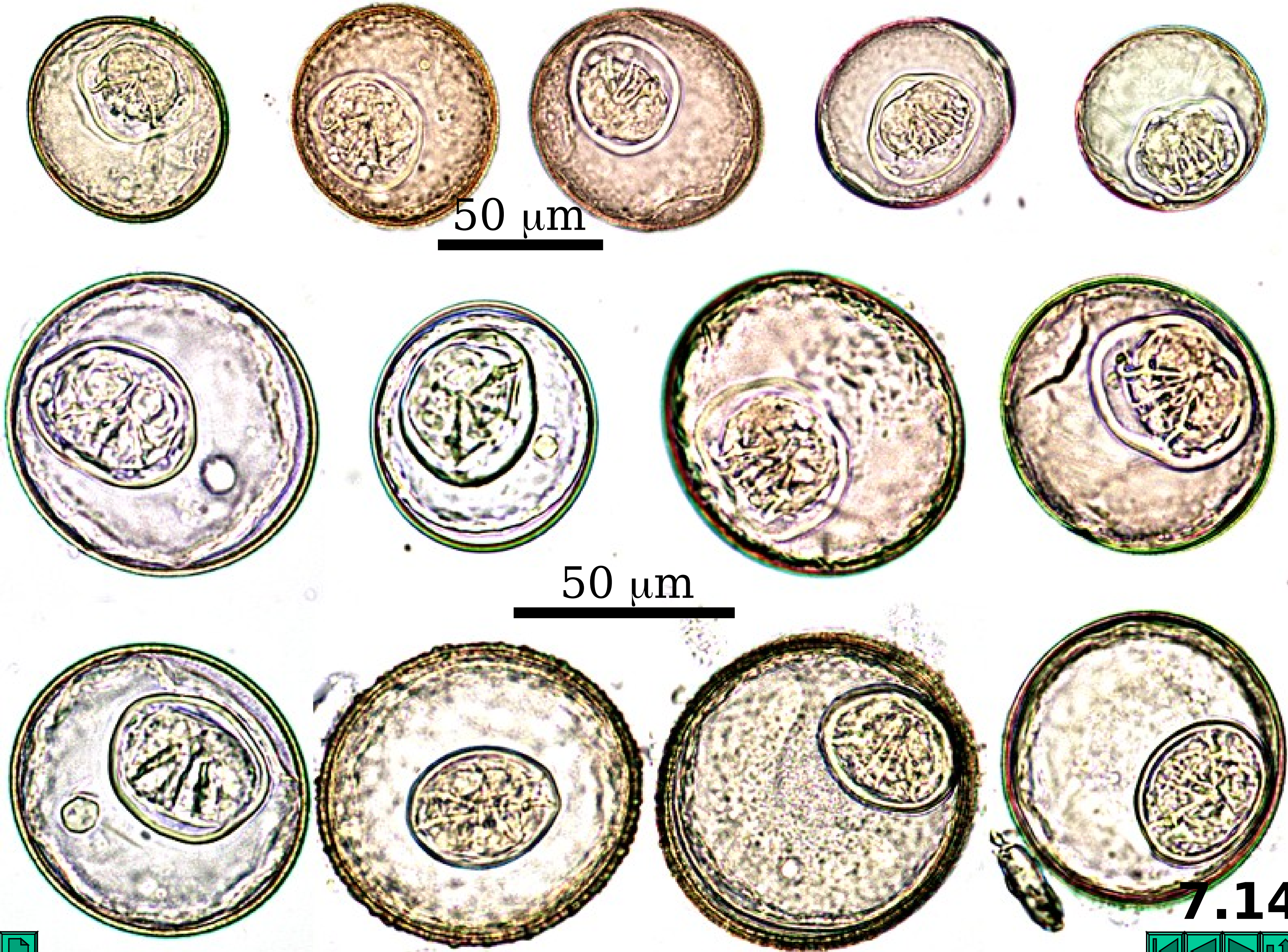


7.1

7.13 Eggs of *Hymenolepis nana*. Top row is at same magnification as trematode eggs in the previous chapter.
Note the oncosphere with hooks (thin arrow), surrounded by an embryophore that has polar filaments at either end (thick arrows). The outermost capsule is separated from the embryophore by a gelatinous granular layer. These eggs are infective not only for an insect intermediate host, but also for the rodent or human definitive host.

- back to adult of *Hymenolepis nana*
- back to eggs of *Hymenolepis diminuta*

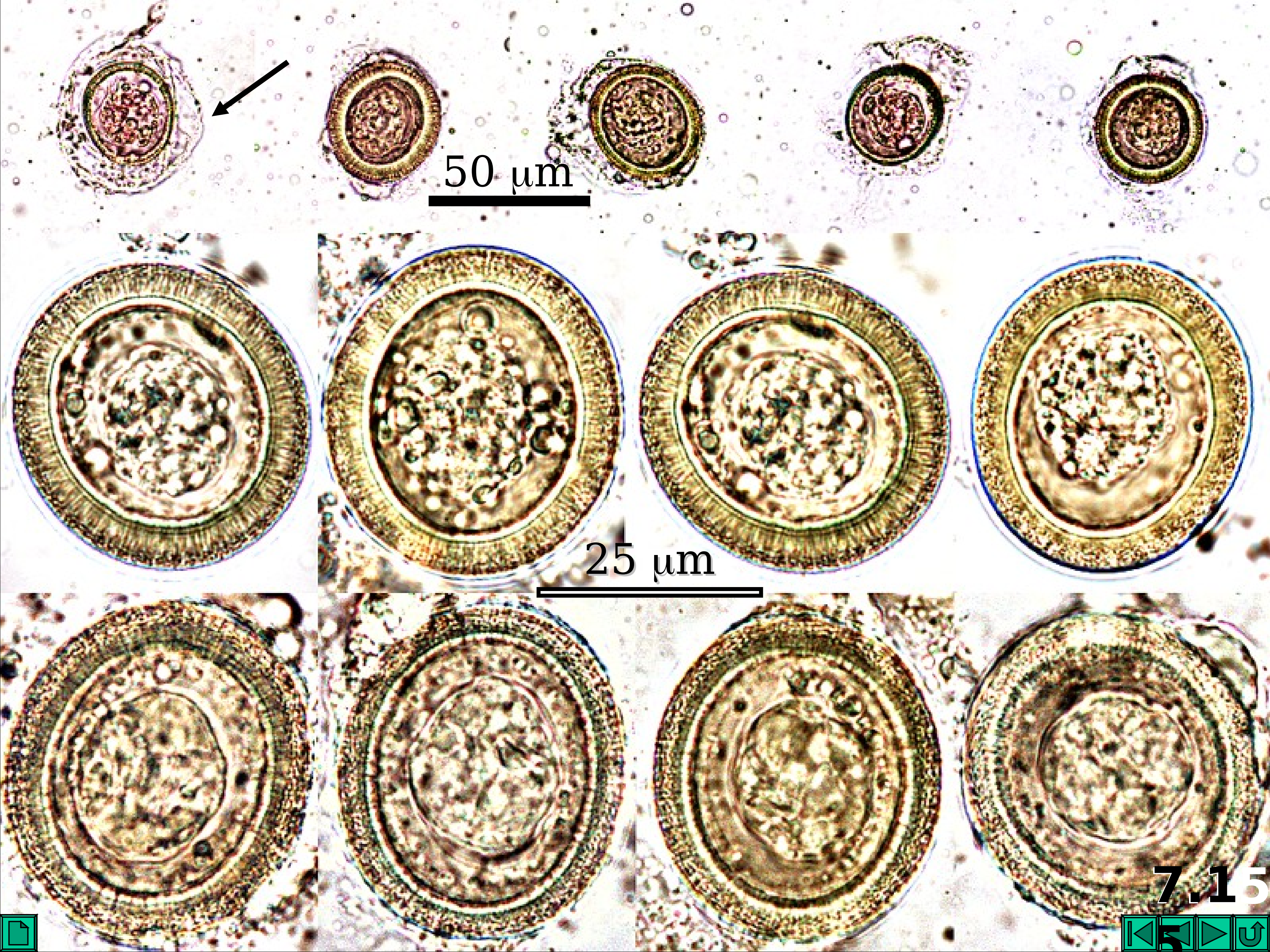




7.14

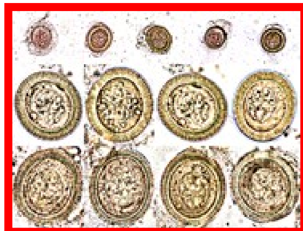
7.14 Eggs of *Hymenolepis diminuta.* Top row is at same magnification as trematode eggs in the previous chapter. As with eggs of *H. nana*, the oncosphere is surrounded by an embryophore, gelatinous layer, and capsule. However, eggs of *H. diminuta* are larger, and the embryophore lacks polar filaments. Note clearly visible hooks in some specimens. These eggs are infective solely for the insect intermediate host, usually a grain or flour beetle. Human infections with the adult result from ingestion of insects harboring the infective cysticercoid, and therefore are rare and usually light.

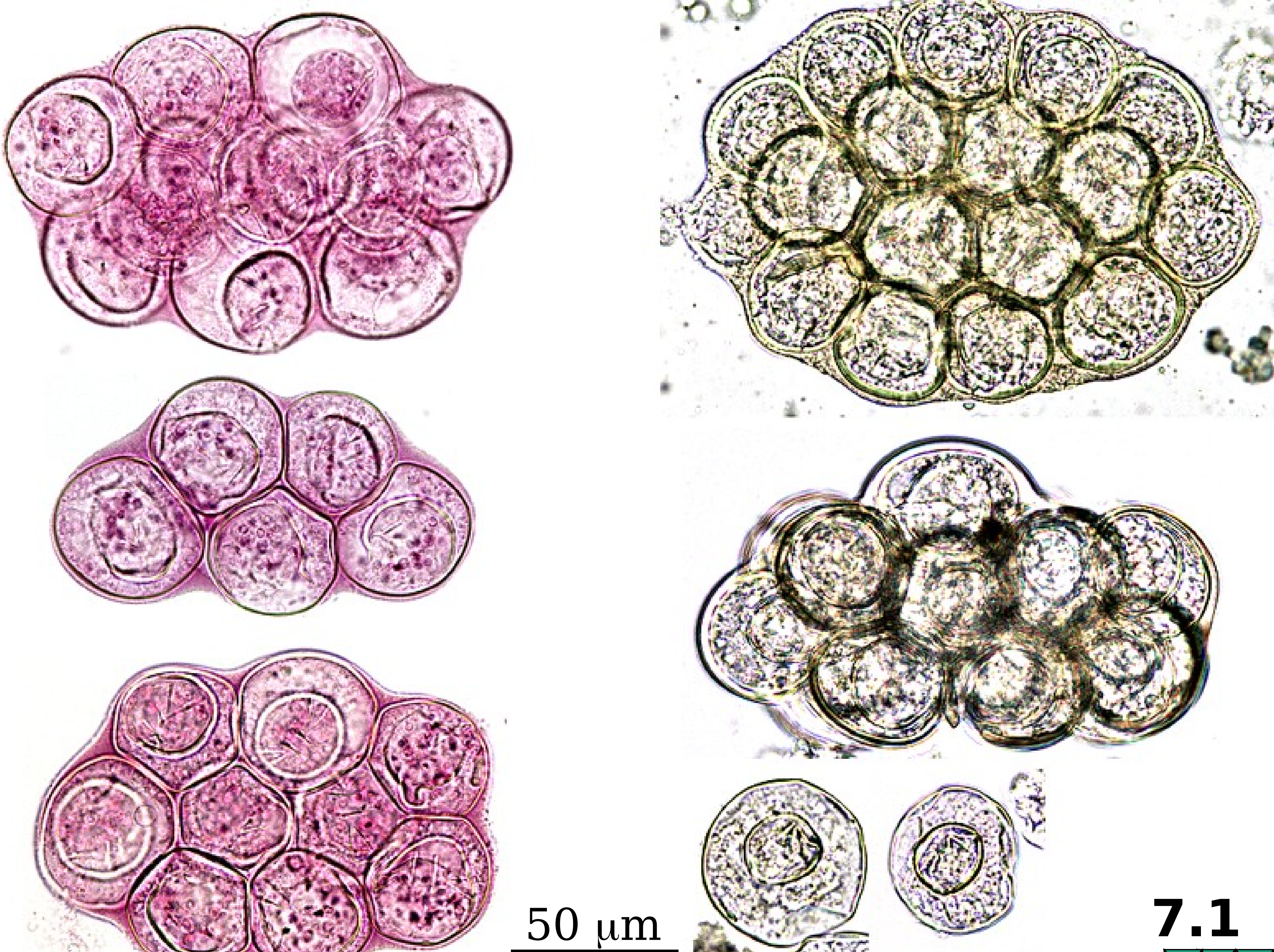
- back to adult of *Hymenolepis diminuta*
- back to eggs of *Dipylidium caninum*


50 µm
25 µm

7.15 Taeniid eggs. Top row (at same magnification as trematode eggs in the previous chapter), *Taenia saginata*, middle row, *T. solium*, and bottom row, *Echinococcus granulosus*. The oncosphere is surrounded by a 2-layered embryophore, and the thicker outer layer has prominent radial striations, a diagnostic feature. The surrounding gelatinous layer and capsule (arrow, top left photograph) are flimsy and often detach from the striated embryophore, which then becomes the outermost layer. Eggs of various taeniids (e.g., *Echinococcus*, *Multiceps*, and *Taenia* spp.) are indistinguishable from one another. Taeniid eggs on the ground may remain infective for over 5 months.

- back to proglottids of *Taenia pisiformis*
- back to adult of *Taenia solium* and *T. saginata*
- back to cysticercus of *Taenia solium*
- back to adult of *Echinococcus granulosus*



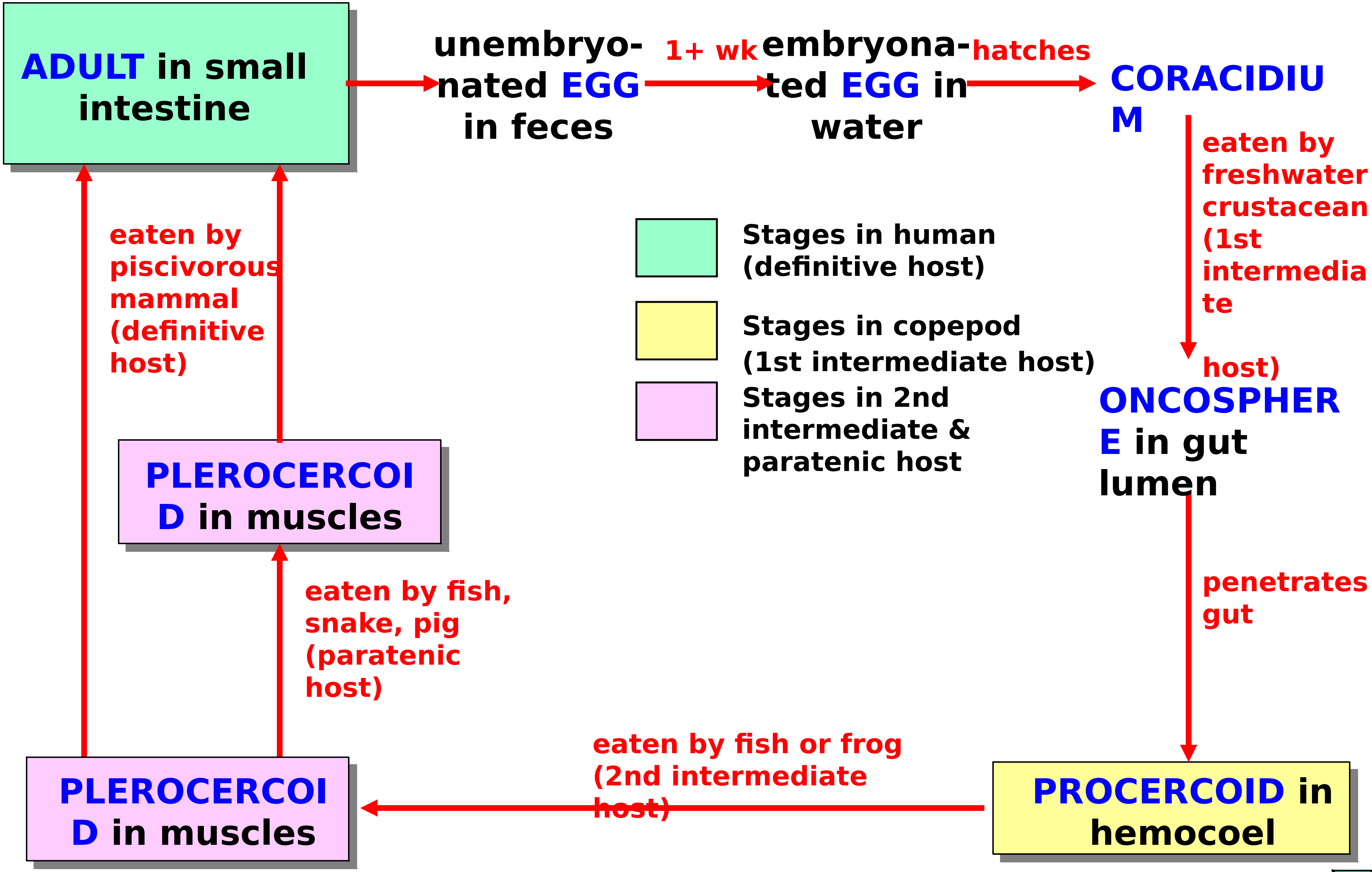


7.1

7.16 Egg capsules of *Dipylidium caninum,* stained and unstained. These are released from disintegrating gravid proglottids, which are quite active after being passed in the feces until they desiccate. The capsules are formed from compartments of the uterus. Individual eggs within the capsule are thin-walled and resemble eggs of *Hymenolepis diminuta* (bottom right photograph).

- back to adult of *Dipylidium caninum*

Life cycle of *Diphyllobothrium latum*



ADULT in small intestine

unembryonated **EGG** in feces

1+ wk

embryonated **EGG** in water

hatches

CORACIDIUM

eaten by freshwater crustacean (1st intermediate host)

ONCOSPHERE in gut lumen

penetrates gut

PROCERCOID in hemocoel

eaten by fish or frog (2nd intermediate host)

PLEROCERCOID in muscles

eaten by fish, snake, pig (paratenic host)

PLEROCERCOID in muscles

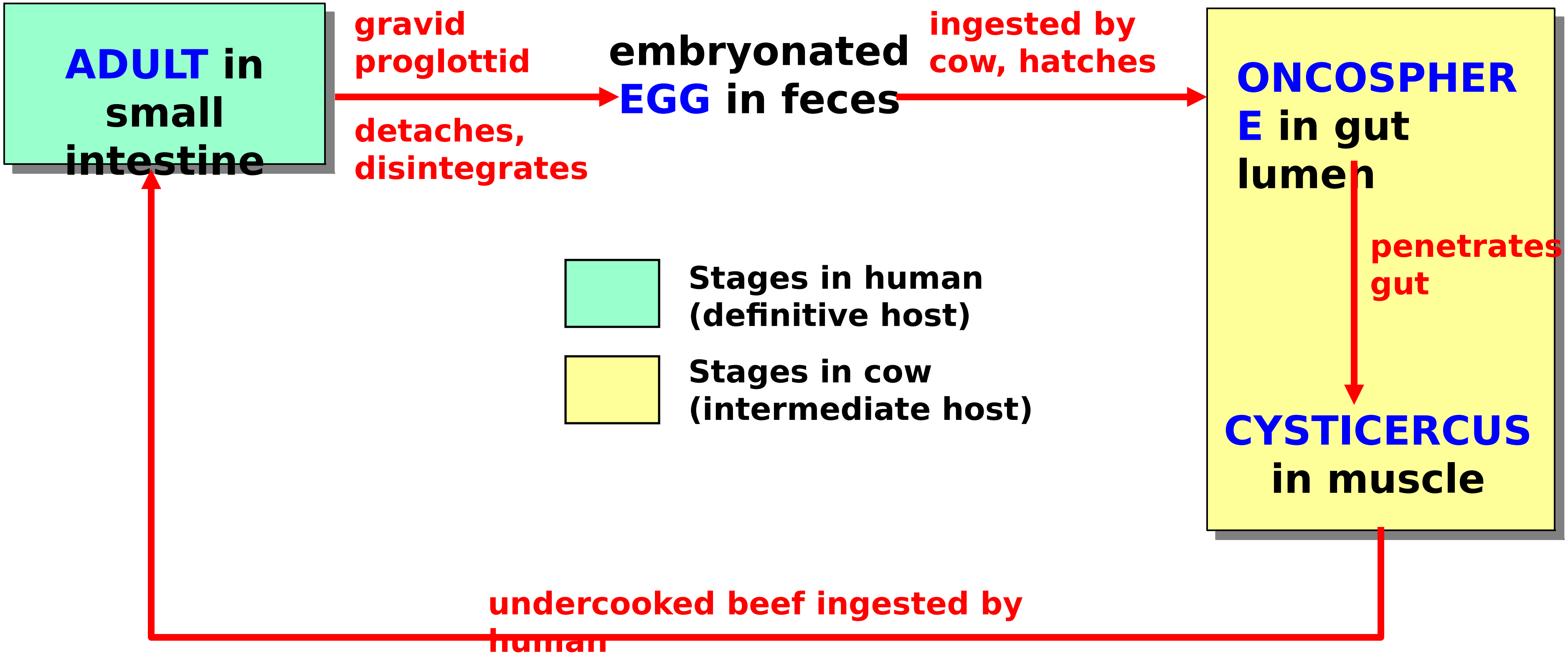
eaten by piscivorous mammal (definitive host)

🟩 Stages in human (definitive host)

🟨 Stages in copepod (1st intermediate host)

🟪 Stages in 2nd intermediate & paratenic host

Life cycle of *Taenia saginata*



ADULT in small intestine

gravid proglottid detaches, disintegrates

embryonated **EGG** in feces

ingested by cow, hatches

ONCOSPHERE in gut lumen

penetrates gut

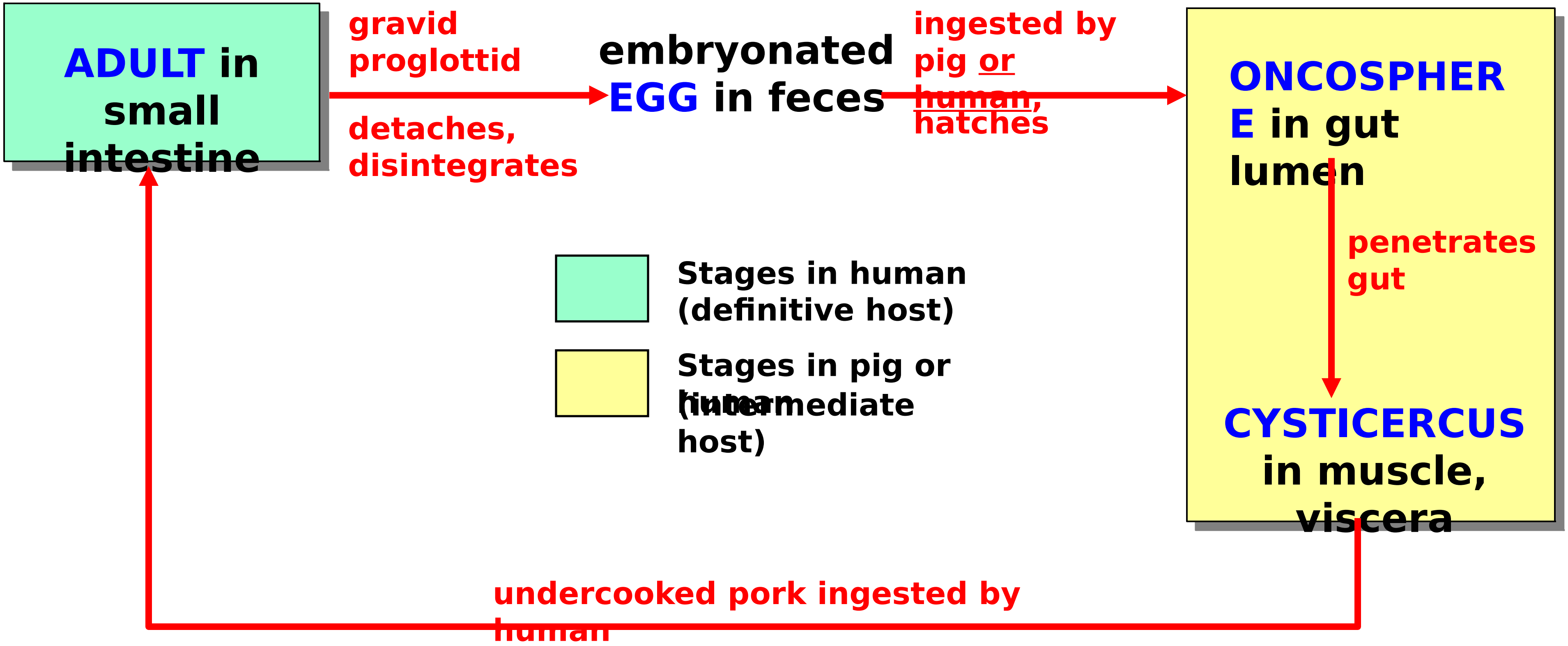
CYSTICERCUS in muscle

undercooked beef ingested by human

🟩 Stages in human (definitive host)

🟨 Stages in cow (intermediate host)

Life cycle of *Taenia solium*



ADULT in small intestine

gravid proglottid detaches, disintegrates

embryonated **EGG** in feces

ingested by pig or human, hatches

ONCOSPHERE in gut lumen

penetrates gut

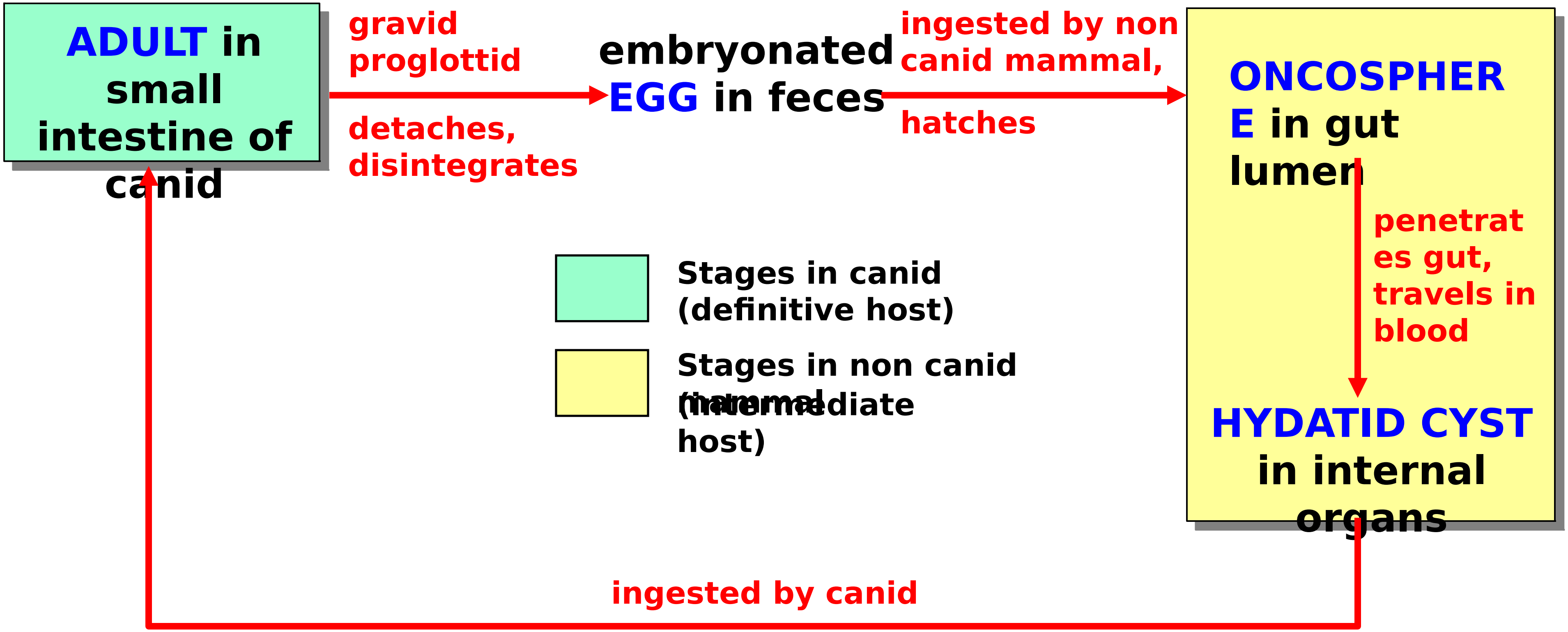
CYSTICERCUS in muscle, viscera

undercooked pork ingested by human

🟩 Stages in human (definitive host)

🟨 Stages in pig or human (intermediate host)

Life cycle of *Echinococcus* spp.



ADULT in small intestine of canid

gravid proglottid detaches, disintegrates

embryonated **EGG** in feces

ingested by non canid mammal, hatches

ONCOSPHERE in gut lumen

penetrates gut, travels in blood

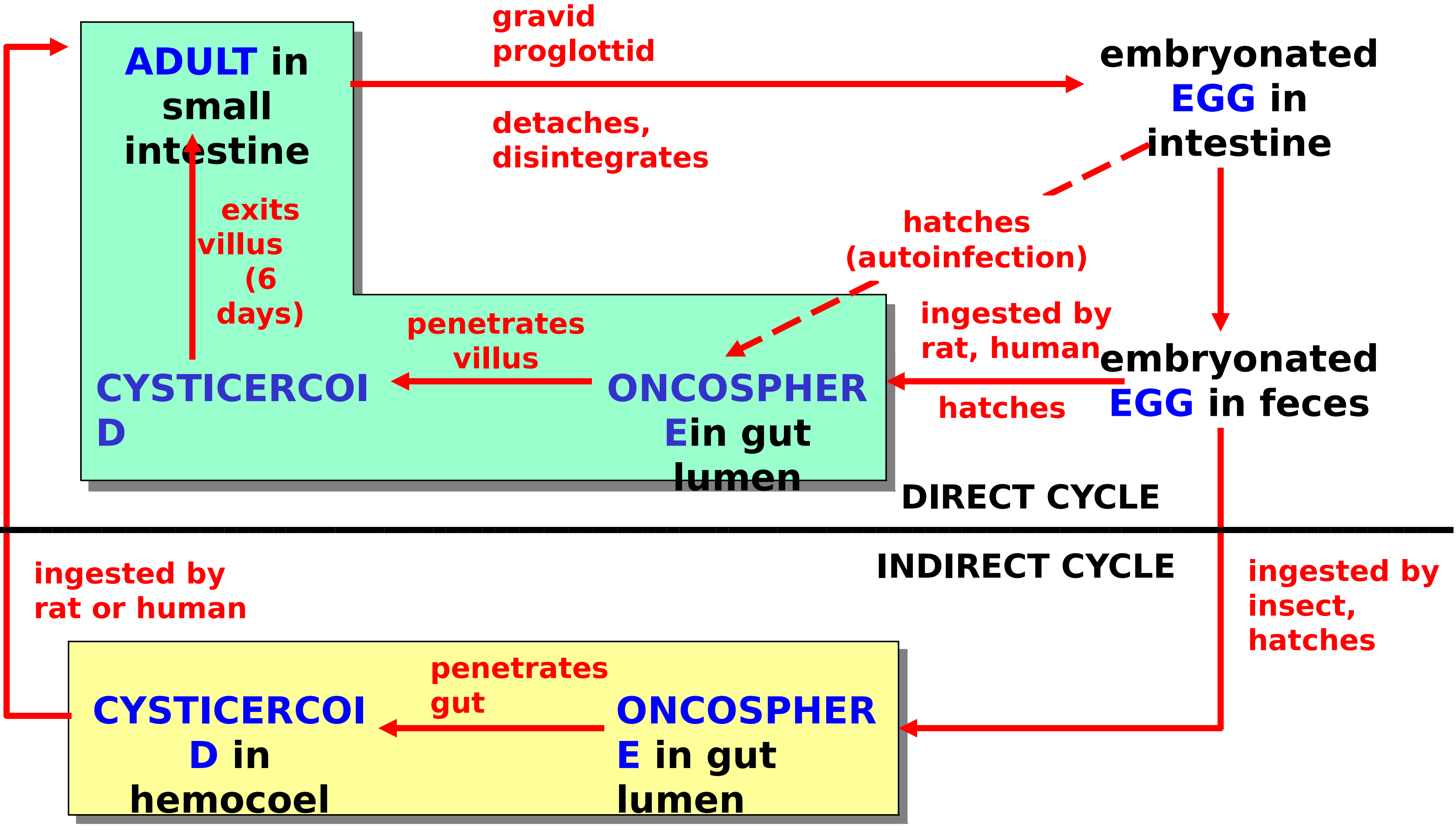
HYDATID CYST in internal organs

ingested by canid

🟩 Stages in canid (definitive host)

🟨 Stages in non canid mammal (intermediate host)

Life cycle of *Hymenolepis nana*



ADULT in small intestine

gravid proglottid

detaches, disintegrates

embryonated **EGG** in intestine

hatches (autoinfection)

exits villus (6 days)

CYSTICERCOID

penetrates villus

ONCOSPHERE in gut lumen

ingested by rat, human

hatches

embryonated **EGG** in feces

DIRECT CYCLE

INDIRECT CYCLE

ingested by rat or human

ingested by insect, hatches

CYSTICERCOID in hemocoel

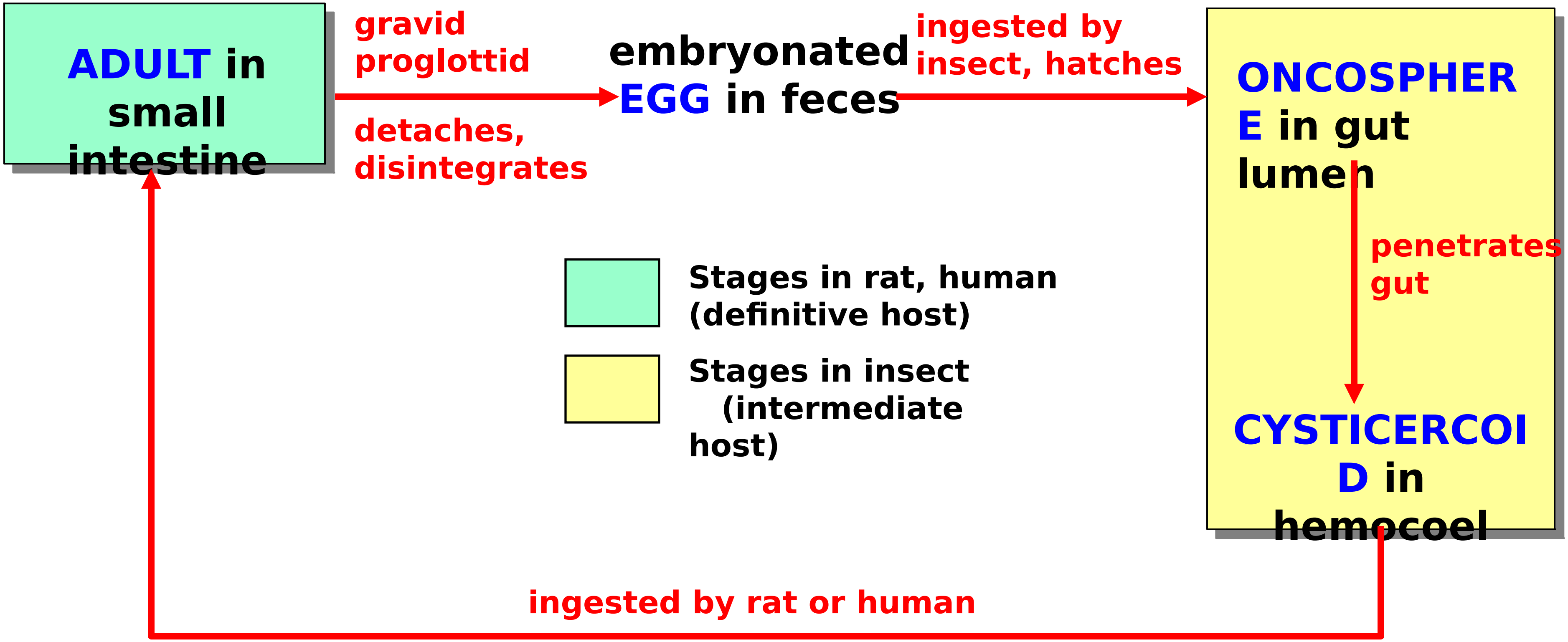
penetrates gut

ONCOSPHERE in gut lumen

🟩 Stages in rat, human (definitive host)

🟨 Stages in insect (intermediate host)

Life cycle of *Hymenolepis diminuta*



ADULT in small intestine

gravid proglottid

detaches, disintegrates

embryonated **EGG** in feces

ingested by insect, hatches

ONCOSPHERE in gut lumen

penetrates gut

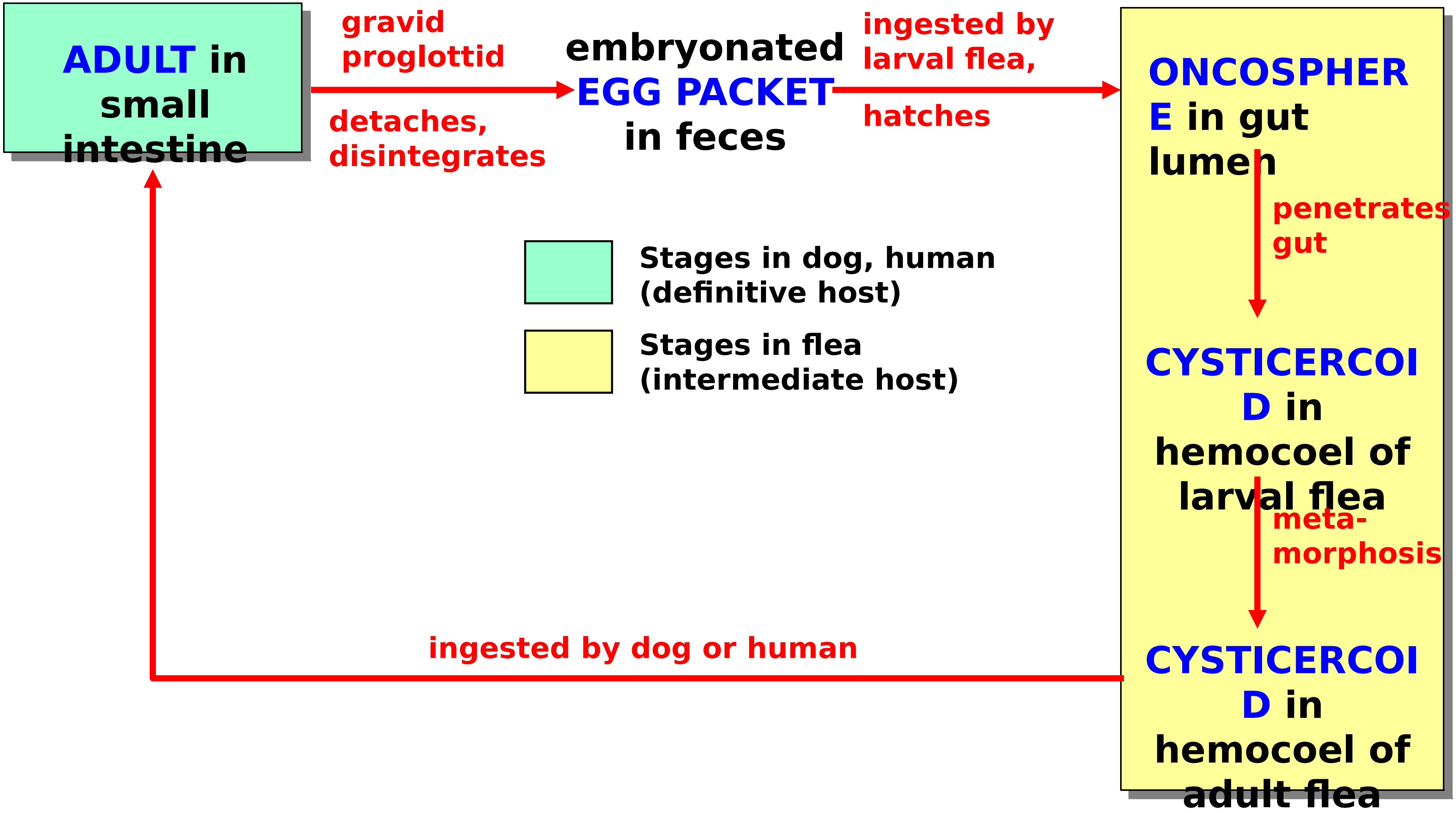
CYSTICERCOID in hemocoel

ingested by rat or human

🟩 Stages in rat, human (definitive host)

🟨 Stages in insect (intermediate host)

Life cycle of *Dipylidium caninum*



ADULT in small intestine

gravid proglottid

detaches, disintegrates

embryonated **EGG PACKET** in feces

ingested by larval flea,

hatches

ONCOSPHERE in gut lumen

penetrates gut

CYSTICERCOID in hemocoel of larval flea

meta-morphosis

CYSTICERCOID in hemocoel of adult flea

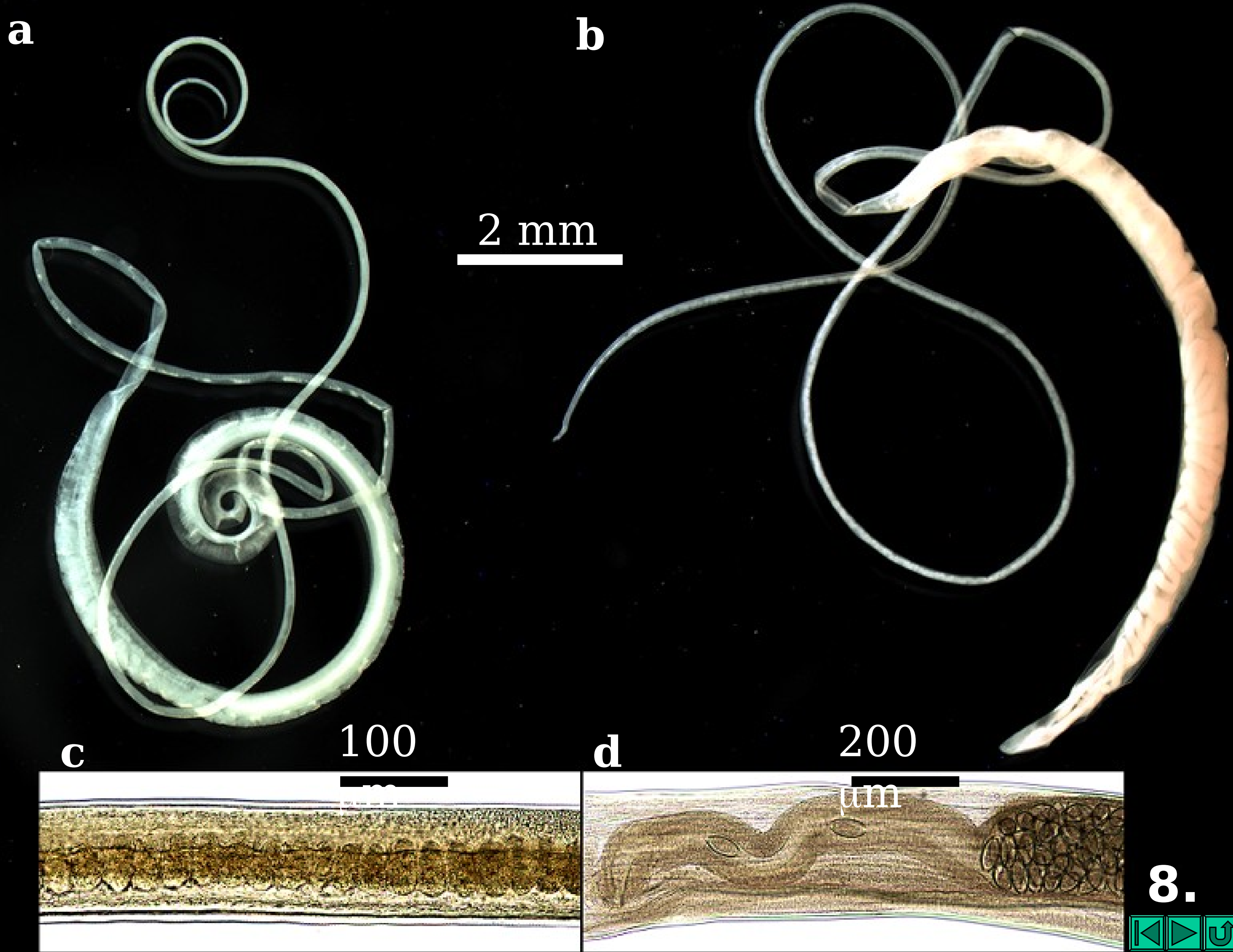
ingested by dog or human

🟩 Stages in dog, human (definitive host)

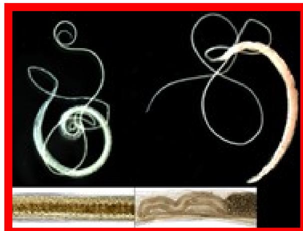
🟨 Stages in flea (intermediate host)

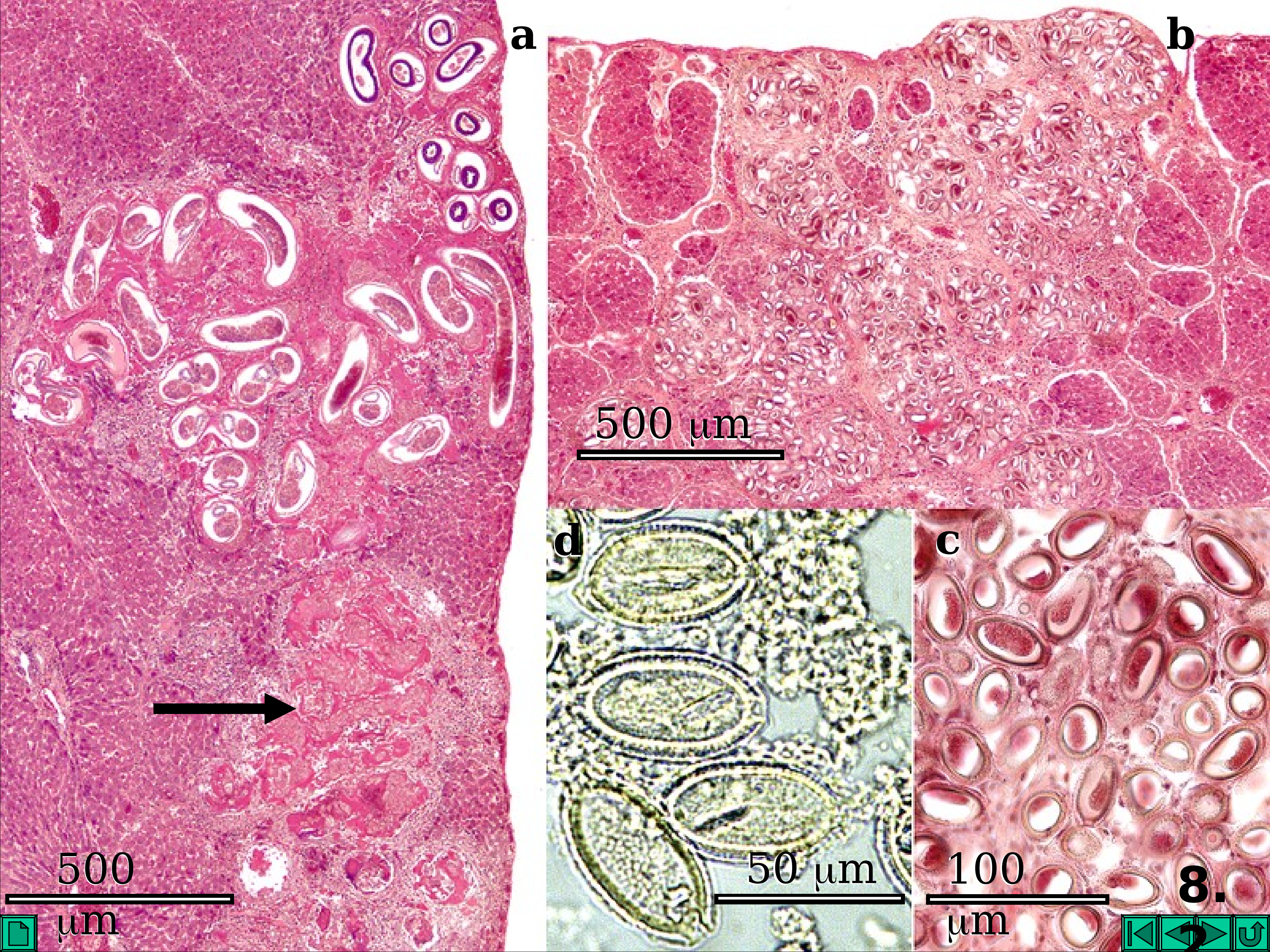
8. Nematodes & Acanthocephalans

- *Trichuris trichiura*
- *Capillaria hepatica*
- *Trichinella spiralis*
- *Strongyloides stercoralis*
- *Necator americanus*
- *Ancylostoma duodenale*
- Rhabditiform vs. filariform larvae
- *Ascaris lumbricoides*
- Larvae of *Ascaris lumbricoides* in lung
- *Enterobius vermicularis*
- *Dirofilaria immitis*
- Microfilariae of *Brugia malayi, Loa loa,* & *Wucheraria bancrofti*
- *Onchocerca volvulus*
- *Simulium* sp. (black fly)
- *Gongylonema ingluvicola*
- Eggs of *Trichuris trichiura*
- Hookworm eggs
- Eggs of *Trichostrongylus* sp.
- Eggs of *Ascaris lumbricoides*
- Eggs of *Toxocara canis*
- Eggs of *Baylisascaris procyonis*
- Eggs of *Enterobius vermicularis*
- Acanthocephalans

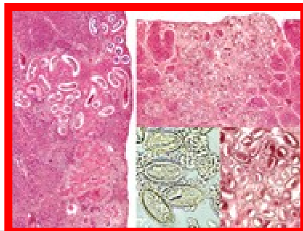

a
b
2 mm
c
100 µm
d
200 µm

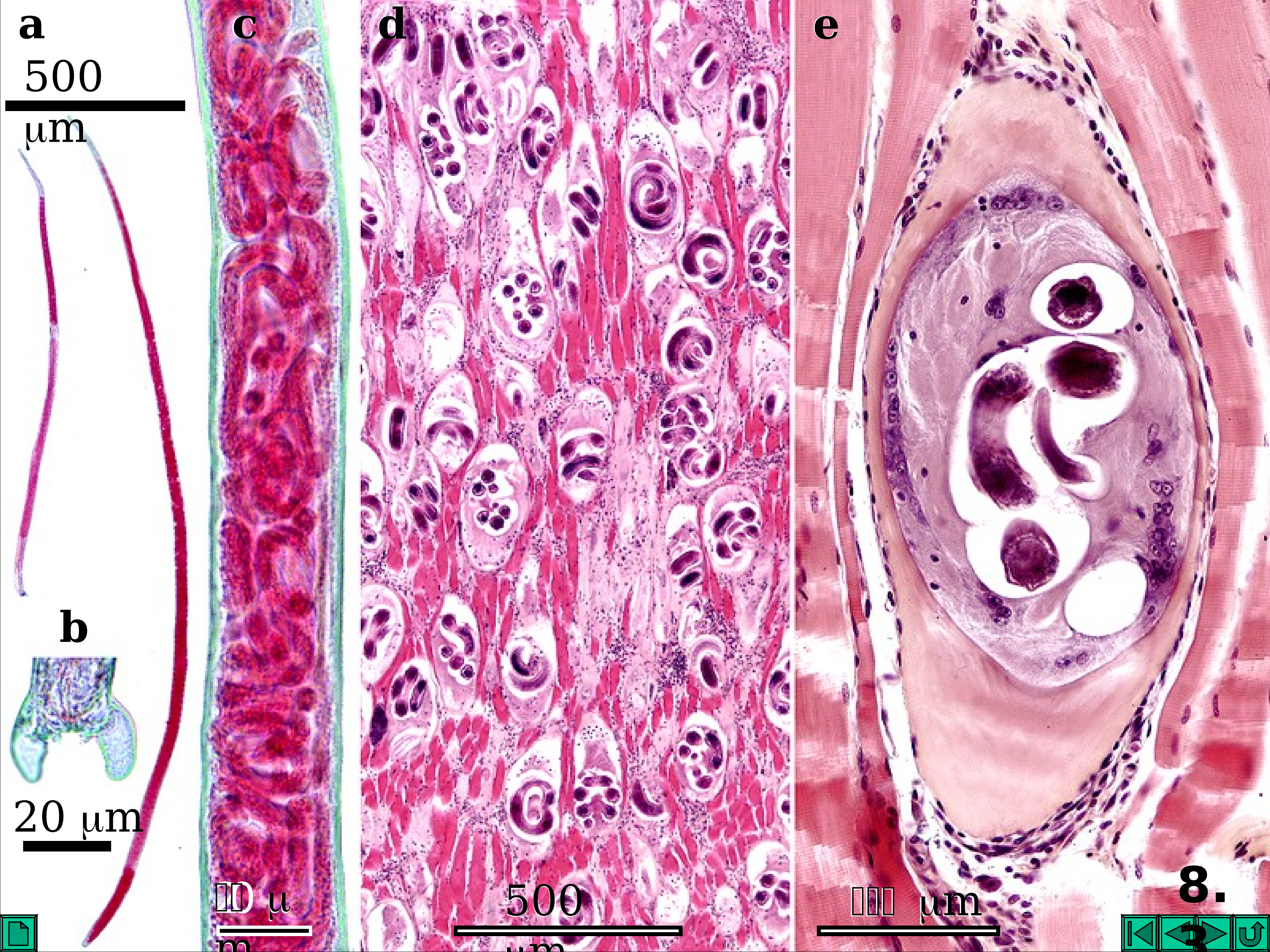
8.1 *Trichuris trichiura*. **a.** Adult male. Note curved posterior end. **b.** Adult female. **c.** Portion of esophagus, surrounded by unicellular glands called stichocytes. **d.** Terminal portion of female reproductive tract, showing uterus packed with eggs, and muscular ovijector containing two eggs awaiting oviposition. These cosmopolitan intestinal parasites have an easily recognizable whip-like shape, hence the common name whipworm. The long, thin anterior end lies buried in the mucosa of the ileocecal region. Because of the mechanical and possibly immune-mediated damage to the mucosa, heavy infections can result in dysentery, anemia, and rectal prolapse. Heavy infections in children, common in some tropical countries, can retard physical and cognitive development.




a
b
500 µm
d
c
500 µm
50 µm
100 µm

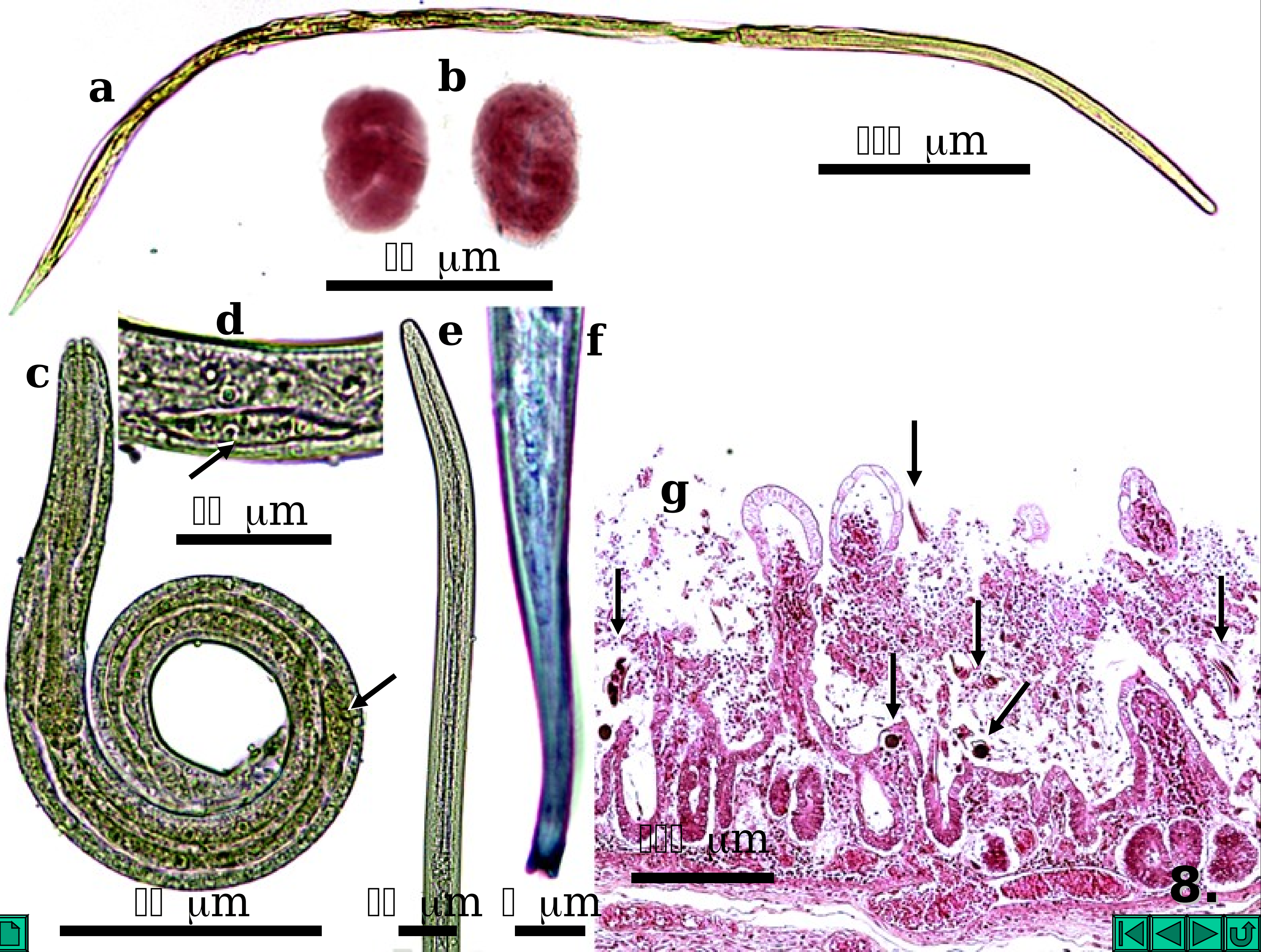
8.2 *Capillaria hepatica.* **a.** Histological section of liver, showing adult female. Note disruption of parenchyma in the area surrounding the worm and in the migration path (arrow). **b.** Histological section of liver showing large masses of eggs displacing parenchyma. **c.** Higher magnification of eggs, which resemble those of *Trichuris spp*., but have thicker, striated shells. **d.** Eggs in smear of infected liver tissue. Normally a parasite of rats, its eggs escape to the outside only with the death of the host. The eggs, which do not develop at body temperature, require several weeks to embryonate on the ground, and are then infective for rats (or humans) that ingest them. Note that fecal contamination is not involved in the transmission (unless from a predator that has consumed the rat). Depending on the volume liver that has been replaced by eggs, infected




a
500 μm
b
20 μm
c
0 μm
d
500 μm
e
μm

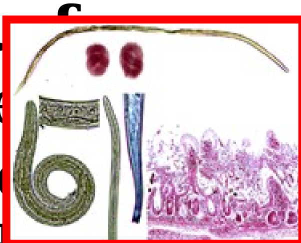
8.

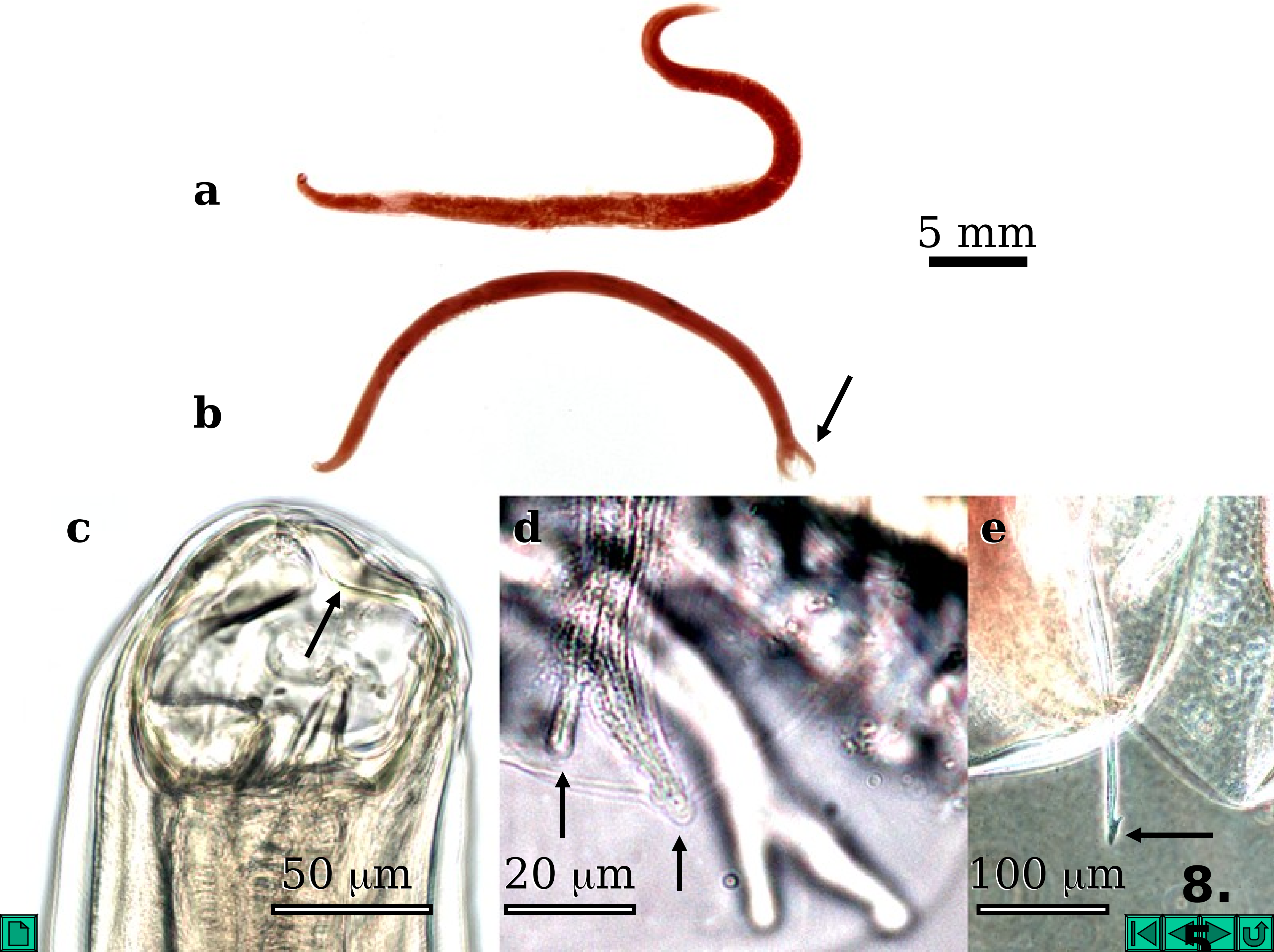
8.3 *Trichinella spiralis*. **a.** Low magnification view of adult male (on left) and female. **b.** Posterior end of male, showing copulatory pseudobursa and papillae. **c.** Portion of adult female, showing uterus packed with L_1s. Each female releases approximately 1,500 L_1s in the intestine of the definitive host. **d.** Numerous juveniles encysted in heavily infected skeletal muscle. **e.** Higher magnification of juvenile in nurse cell. This nematode is unusual in that it is an intracellular parasite, and the definitive host also serves as intermediate host. Infection occurs when infective encysted larvae are eaten in uncooked meat, usually pork (although an outbreak occurred in France due to ingestion of infected horse meat). Humans are compatible hosts, but they are a “dead end” for the parasite in the sense that their muscles usually not eaten by another animal. This parasite is qu pathogenic, damaging not only skeletal muscles


a
b
[illegible] μm
[illegible] μm
d
c
e
f
[illegible] μm
g
[illegible] μm
[illegible] μm
[illegible] μm
[illegible] μm
8.

8.4 *Strongyloides stercoralis*. **a.** Adult parasitic female. Parasitic males do not occur in this species. However, *S. stercoralis* can undergo a free-living (heterogonic) cycle on the soil, in which males do occur. **b.** Embryonated eggs, from a culture of free-living worms. Although the female deposits embryonated eggs in the intestine, these usually hatch before passing out in the feces, and as a result it is the L_1, rather than the egg, that is typically found in a fecal specimen. **c.** Rhabditiform (L_1) worm. Note the characteristic rhabditiform esophagus (with a constricted isthmus region) and the prominent genital primordium (arrow). **d.** Higher magnification of genital primordium (arrow). **e.** Anterior end of filariform (L_3) infective larva, showing straight esophagus lacking an isthmus. **f.** Posterior end of filariform larva, showing notche tail. **g.** Histological section of infected intestine showing numerous adult females (arrows) invad

- back to rhabditiform larva of hookworm

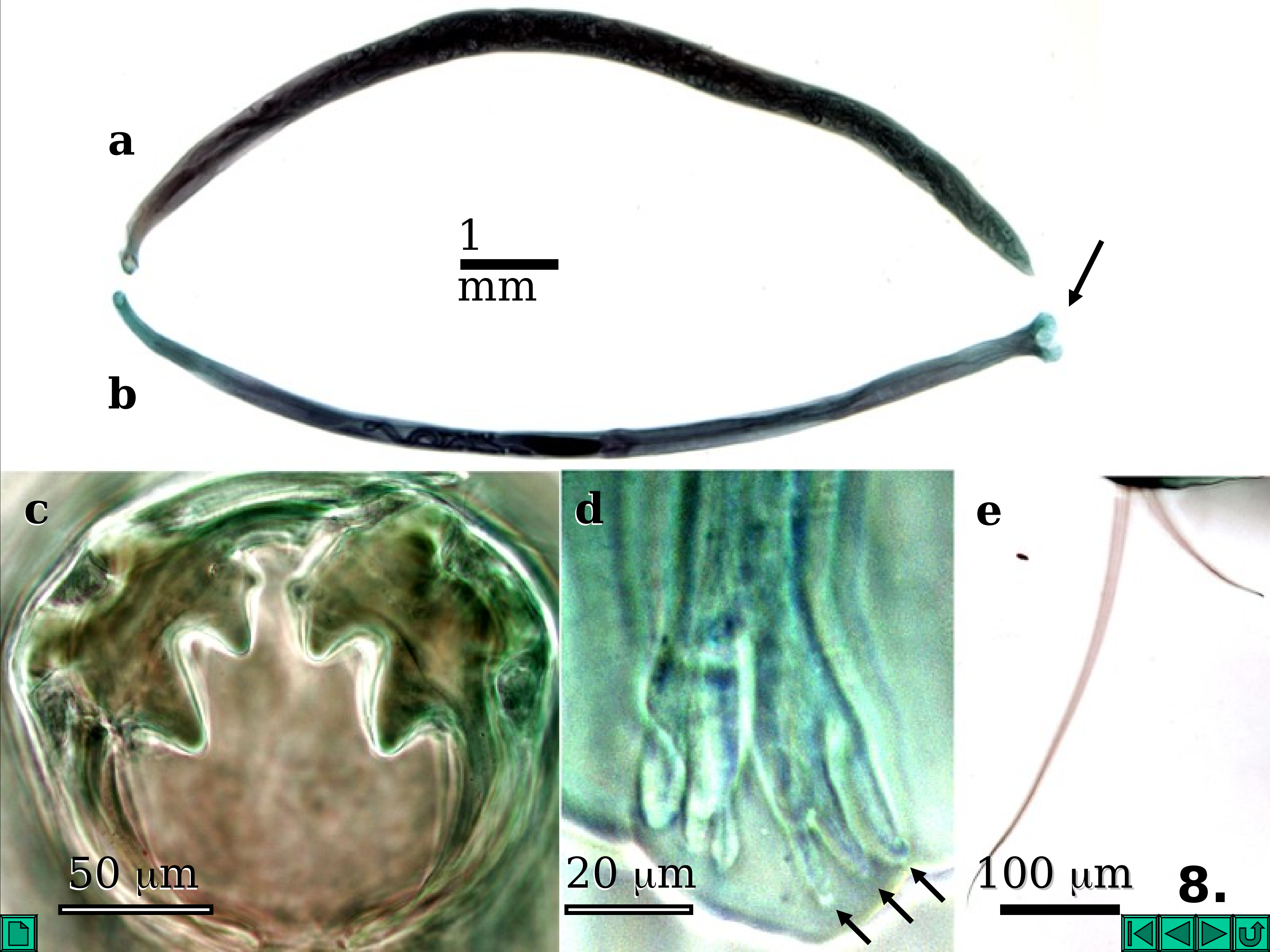



a
5 mm
b
c
50 µm
d
20 µm
e
100 µm

8.5

8.5 *Necator americanus*. **a.** Adult female. **b.** Adult male. Note the posterior copulatory bursa (arrow). Both specimens show dorsal curvature of the anterior end, hence the name “hookworm.” **c.** Buccal capsule, showing cutting plate (arrow). **d.** Dorsal rays of the copulatory bursa, showing 2 branches at the end of each fork (arrows). **e.** Spicules of male, which are fused and form a hook at the tip (arrow). Besides structural differences, *N. americanus* is more prevalent than *Ancylostoma duodenale* everywhere except southern Europe, and its life cycle differs slightly from that of *A. duodenale* (i.e., no developmental arrest in immune hosts; a requirement for migration through the lung). Heavy infection with these blood-feeding worms causes anemia an symptoms of protein malnourishment, which c be fatal.

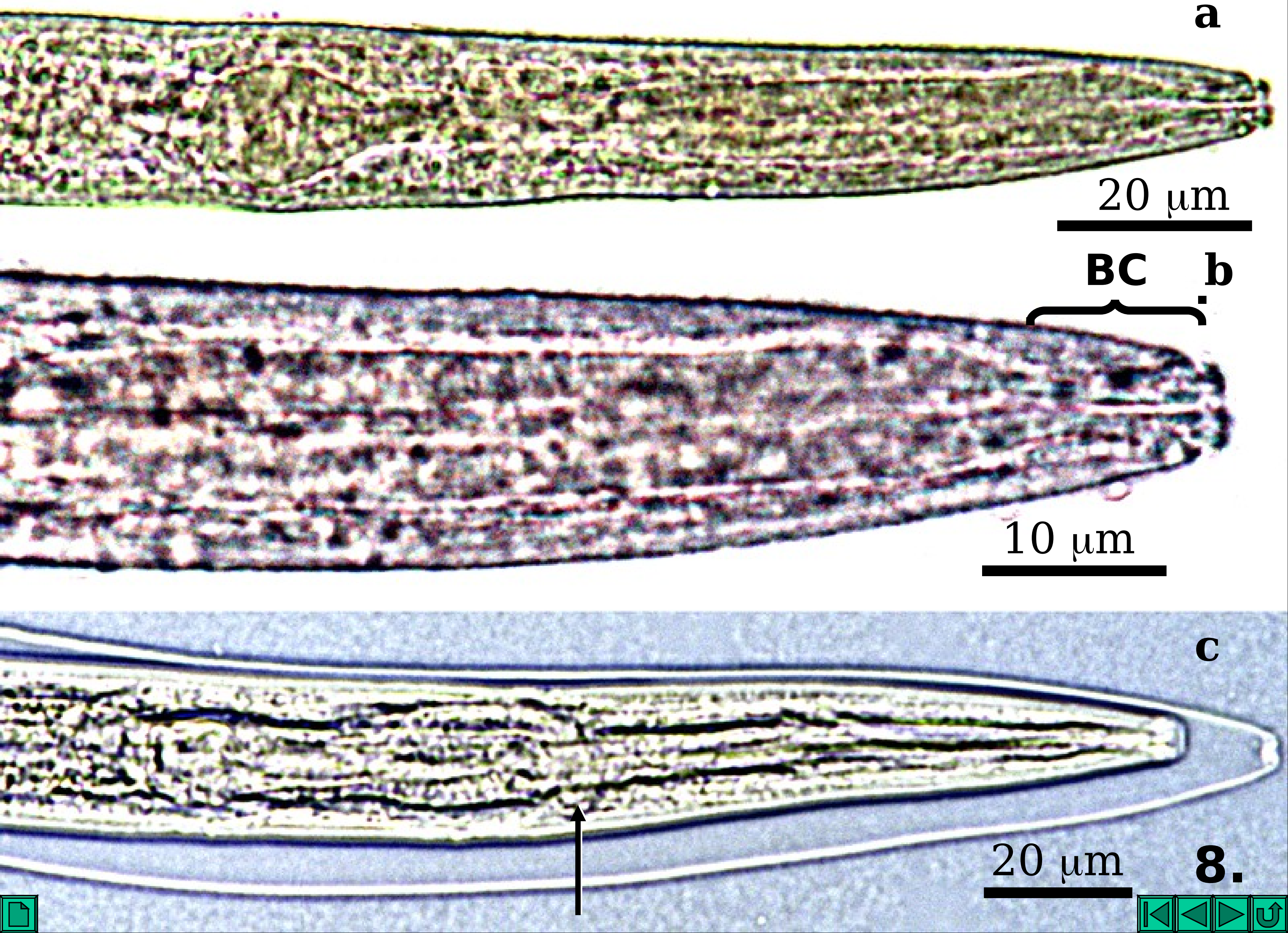
- back to hookworm eggs


a
1 mm
b
c
50 µm
d
20 µm
e
100 µm

8.

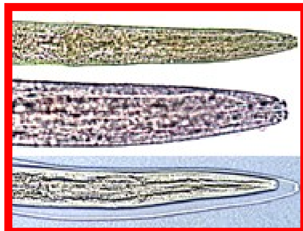
8.6 *Ancylostoma duodenale*. **a.** Adult female. **b.** Adult male. Note the posterior copulatory bursa (arrow). Both specimens show dorsal curvature of the anterior end, hence the name "hookworm." **c.** Buccal capsule, showing the large ventral teeth. **d.** Dorsal ray of the copulatory bursa, showing 3 branches at the end of each fork (arrows). **e.** Spicules of male, which are not fused. Besides structural differences, *A. duodenale* is less prevalent than *Necator americanus* everywhere except southern Europe, and its life cycle differs slightly from that of *N. americanus* (i.e., developmental arrest occurs in immune hosts; no requirement for migration through the lung). Heavy infection with these blood-feeding worms causes anemia and symptoms of protein malnourishment, which can be fatal.

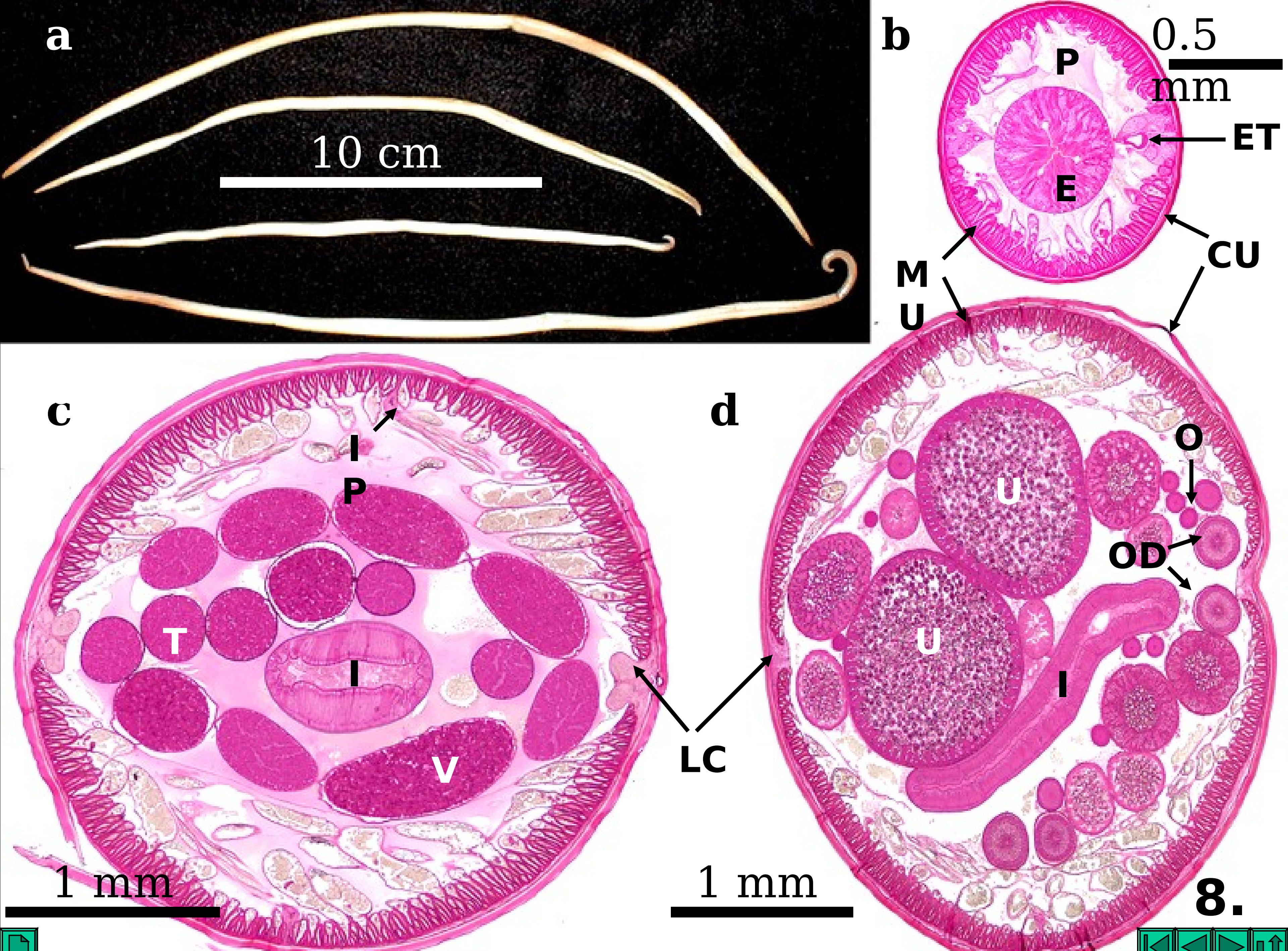
- back to hookworm eggs


a
20 µm
BC
b
10 µm
c
20 µm

8.

8.7 Rhabditiform vs. filariform larvae. **a.** Anterior end of rhabditiform (L_1) hookworm larva. A corpus, isthmus, and end bulb are all present in the esophagus. **b.** Higher magnification of anterior end of rhabditiform hookworm larva, showing large buccal capsule (BC). This feature allows it to be distinguished from the rhabditiform larva of *Strongyloides stercoralis*, which also has a conspicuous genital primordium. **c.** Anterior end of filariform (L_3) hookworm larva. No isthmus is present in the esophagus, although a nerve ring is visible (arrow). This is the infective larval stage. Unlike the filariform larva of *Strongyloides stecoralis*, the tip of the tail lacks a notch.



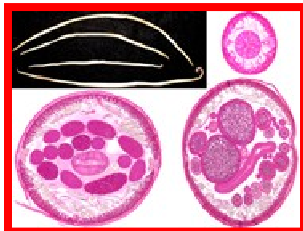

a
10 cm
b
0.5 mm
P
ET
E
CU
M U
c
I P
P
T
I
V
LC
d
U
U
O
OD
I
1 mm
1 mm

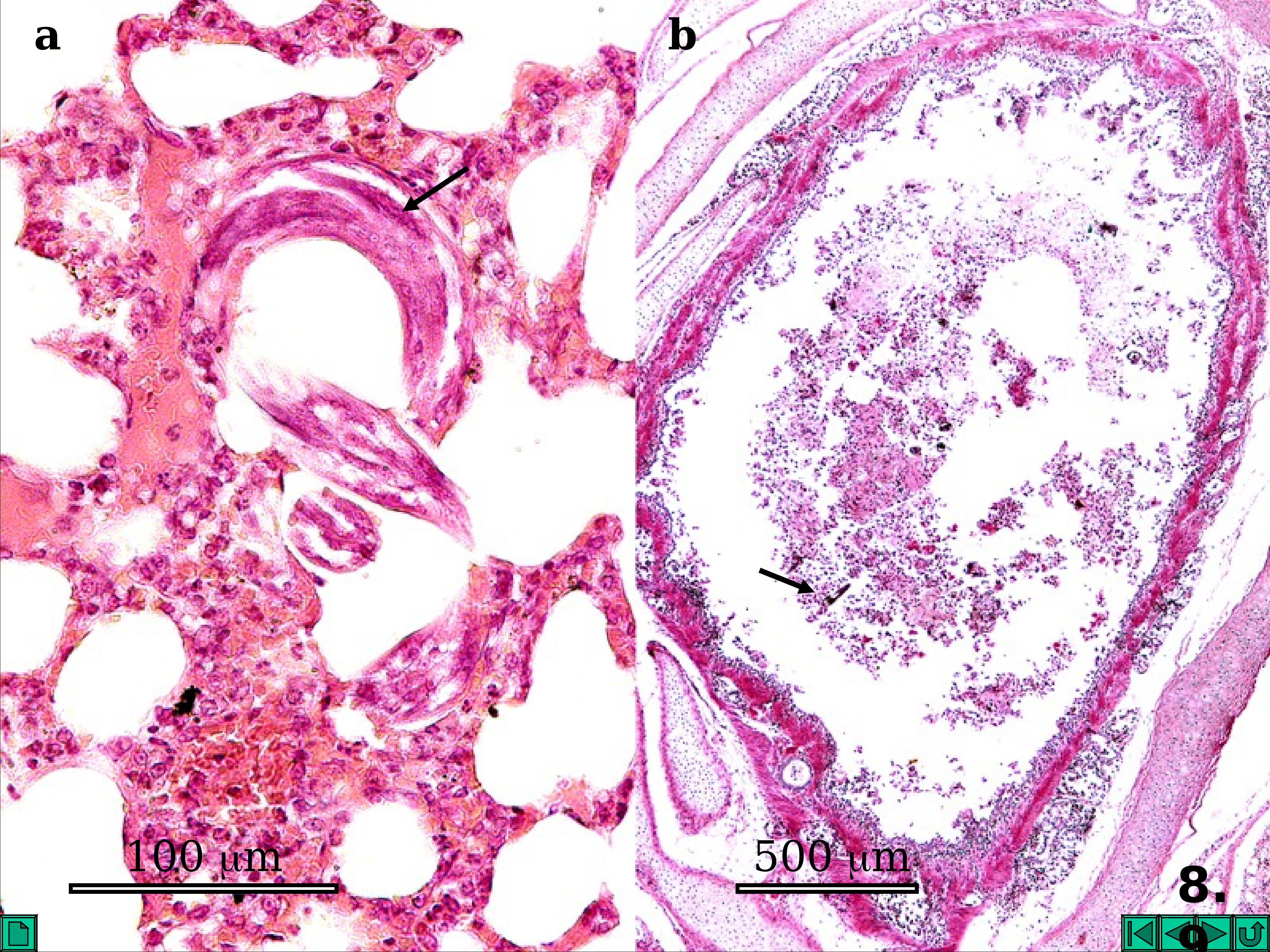
8.

8.8 *Ascaris lumbricoides* adults. **a.** Adult females (top) and males (bottom). Note curved posterior end of male. **b.** Cross section at the level of the esophagus. Note the triradiate lumen of the esophagus (E), a feature of all nematodes. **c.** Cross section of male. **d.** Cross section of female. CU, cuticle; ET, excretory tubules; I, intestine; IP, innervation processes; LC, lateral cords; MU, longitudinal muscles; O, ovary; OD, oviduct; P, pseudocoel; T, testis; U, uterus, with eggs; V, vas deferens. In heavy infections pneumonitis results from lung damage during larval migration. Large numbers of adults can cause malnutrition, allergic symptoms, and fatal intestinal blockage, and wandering worms can invade visceral organs or cause asphyxiation if aspirated.

8.8a from J.T. Sullivan, *Electronic Atlas of Parasitology*, 1.0. Copyright © 1990 McGraw-Hill, Inc., Dubuque, IA. Reprinted by permission.

- back to eggs of *Toxocara canis*
- back to eggs of *Baylisascaris procyonis*

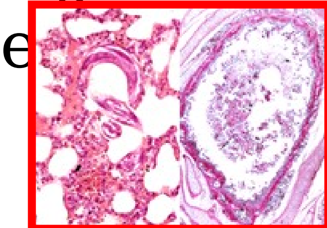


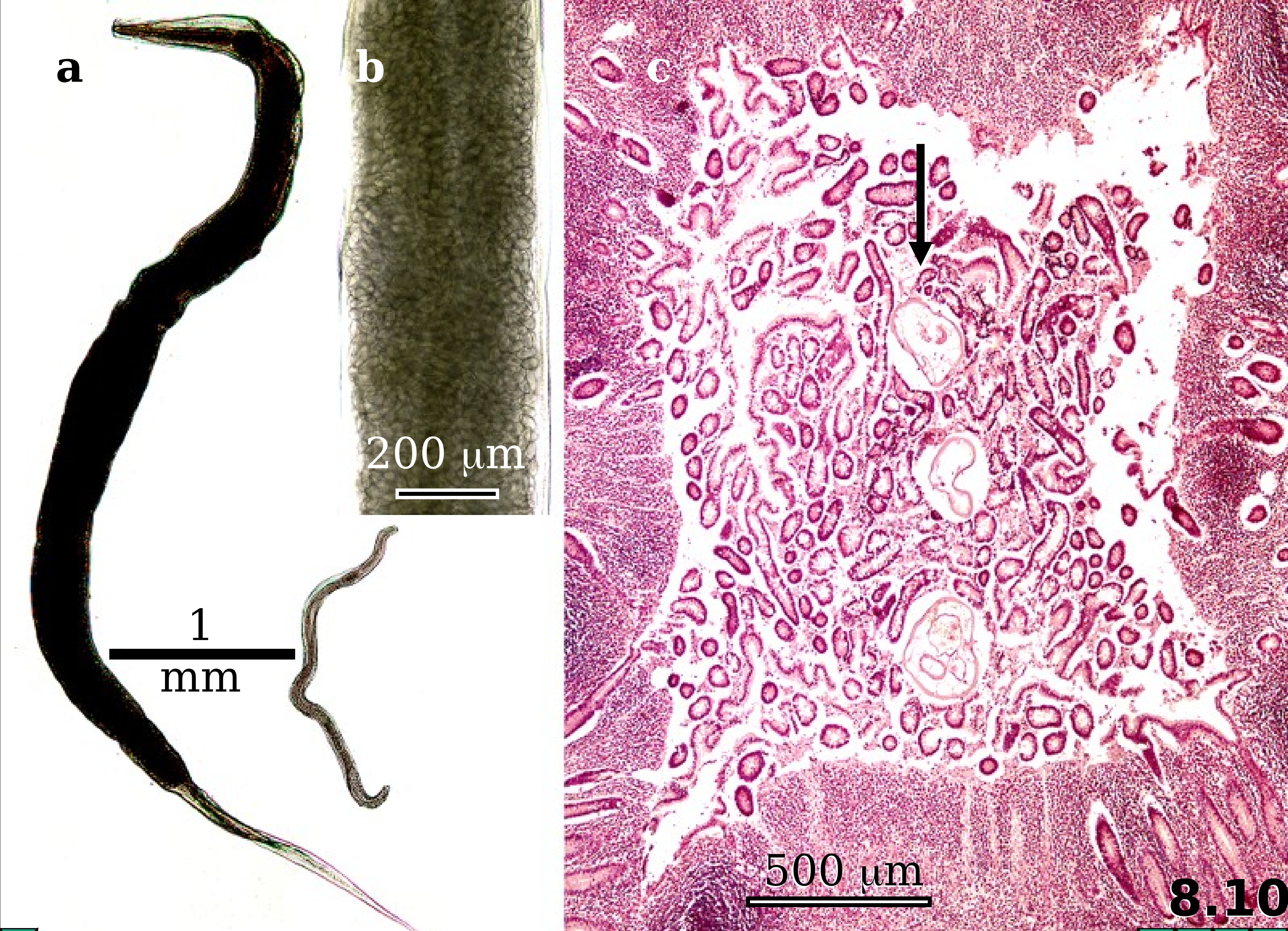

a
100 µm
b
500 µm

8.9

8.9 L_2s of *Ascaris lumbricoides* in lungs. Although larvae hatch from eggs in the duodenum, which is the location for the adult worm, they undergo a complex migration by penetrating into the mucosa and traveling via the blood to the lungs, where they molt twice to the L_4 stage. They then break into an alveolus, pass up to the pharynx, and are swallowed. Upon reaching the duodenum for the second time, they undergo the final molt and develop into adults. **a.** Juvenile (arrow) breaking into alveolus. Note inflammation (pneumonitis) in the interstitial tissue. **b.** Bronchus containing inflammatory cells and larvae (arrow), which are traveling upward to the pharynx prior to being swallowed. Lung damage from heavy infections, especially if complicate bacterial superinfection, can be fatal.

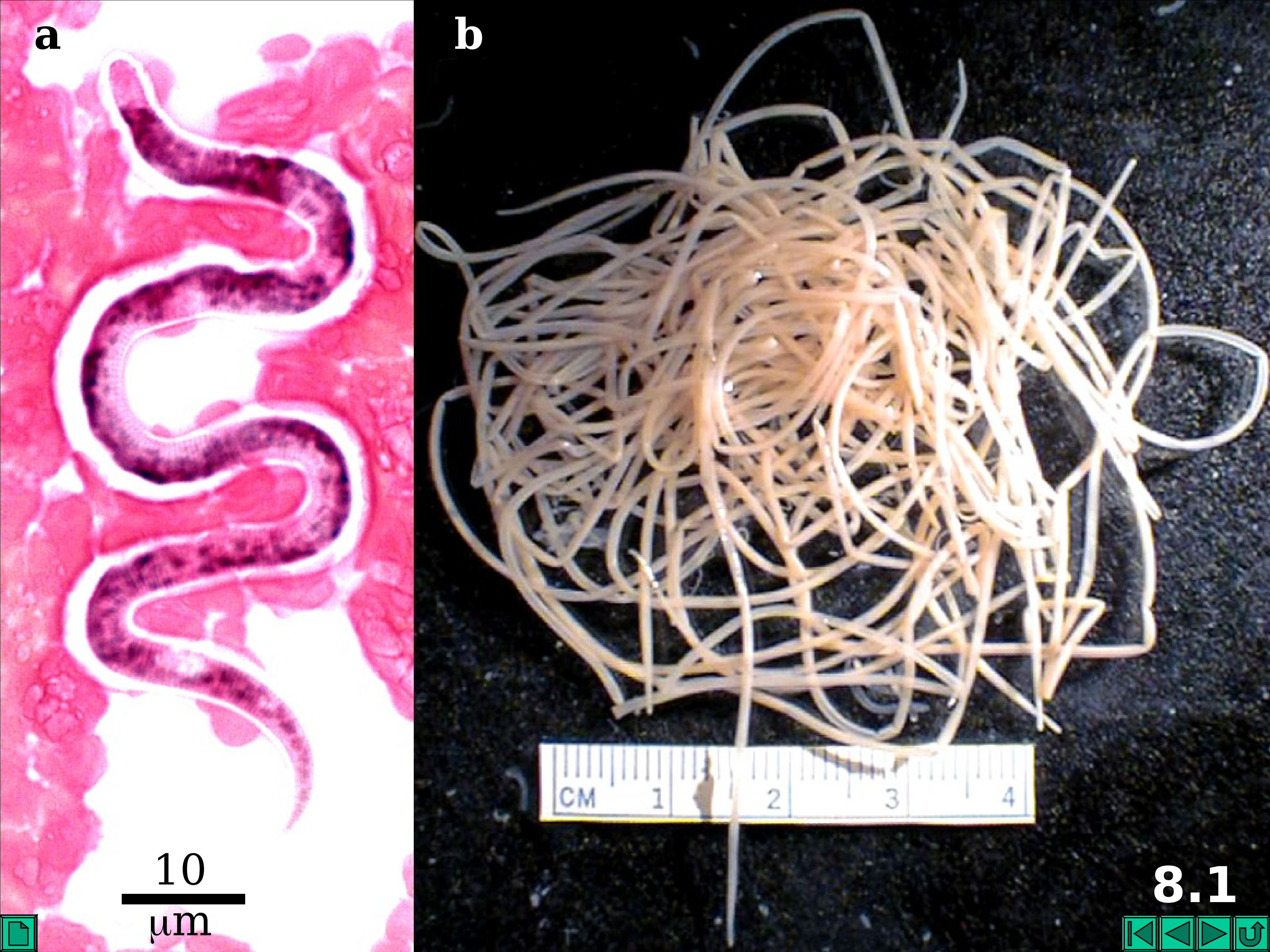
back to adult of *Ascaris lumbricoides*




a
b
c
200 μm
1
mm
500 μm

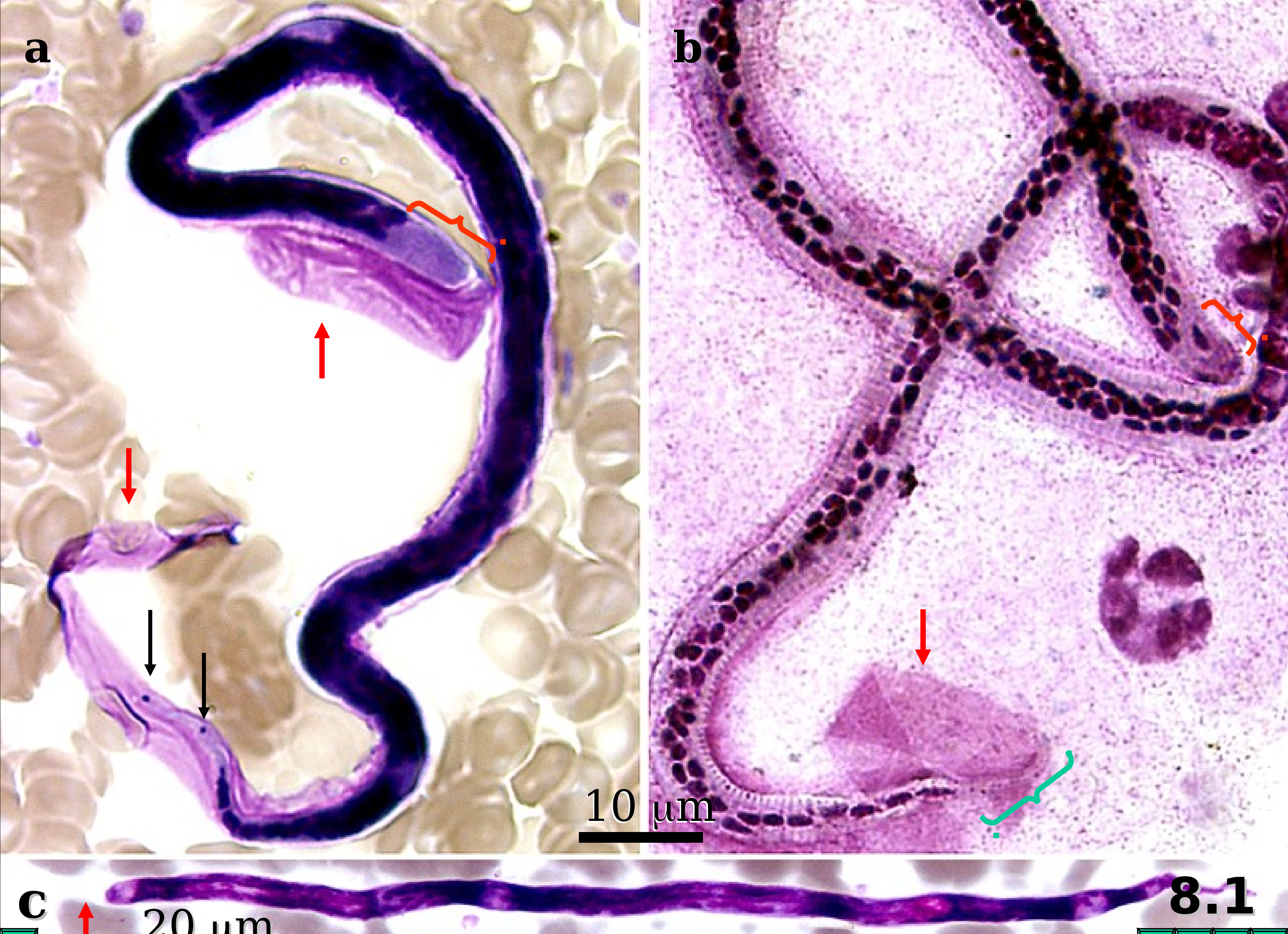
8.10

8.10 *Enterobius vermicularis*. **a.** Adult male (on right) and female. Note long pointed tail of female, hence the name “pinworm.” **b.** Higher magnification of the female, showing the gravid uterus filling the pseudocoelom. **c.** Histological section of appendix, showing three cross sections of pinworms in the lumen (arrow). Although often residing in the appendix, the worms are not believed to cause appendicitis. Infection occurs when the eggs containing L_3s are inhaled or swallowed. The major symptom of infection is perianal itching, although more serious problems can result if tissue invasion occurs, and adults sometimes wander into the female reproductive tract.


a
10 μm
b
CM 1 2 3 4

8.1

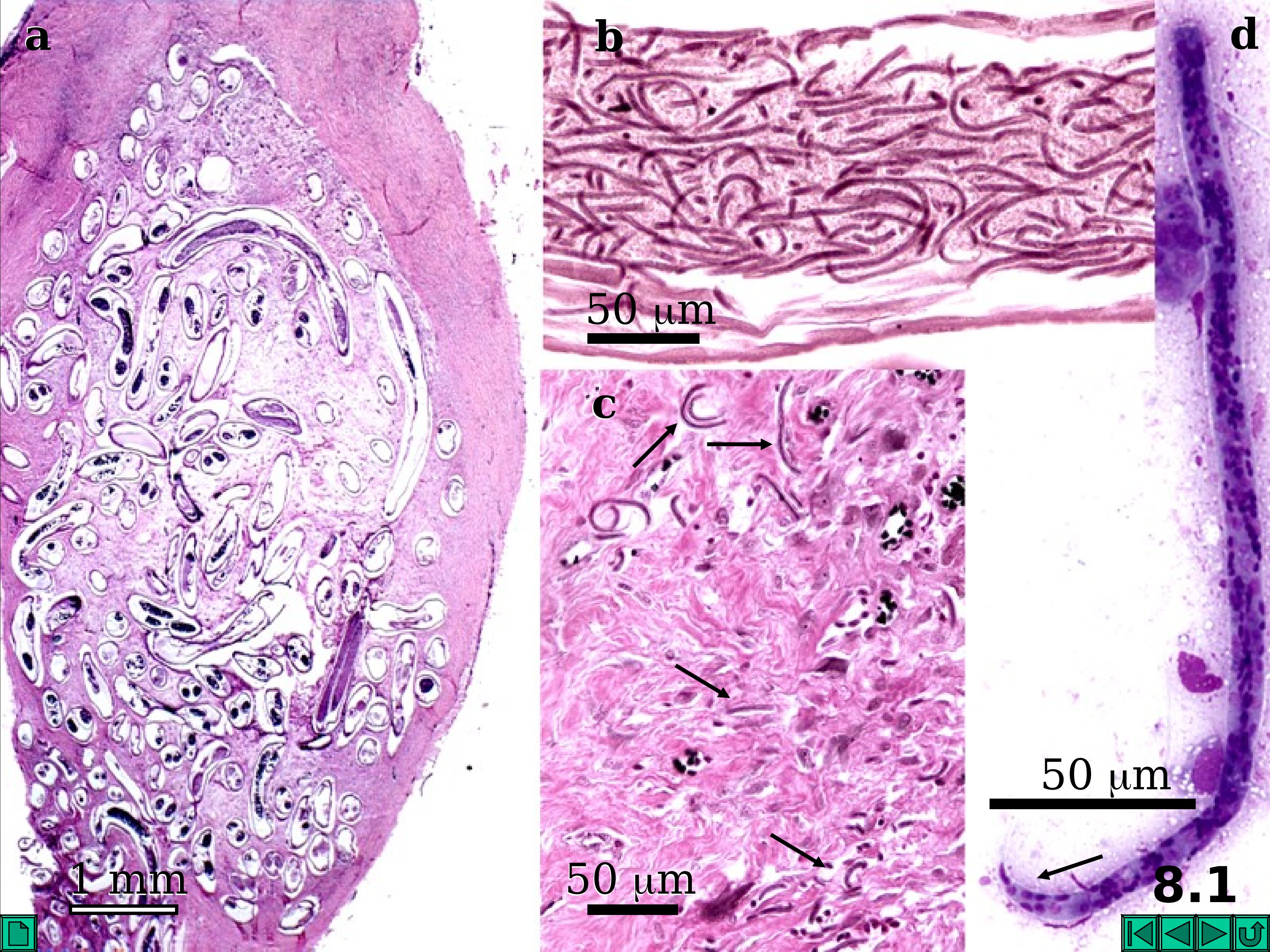
8.11 *Dirofilaria immitis*. **a.** Microfilaria in dog peripheral blood smear. In this species the microfilaria, which is an incompletely developed L_1, does not possess a sheath (i.e., the egg capsule), and nuclei do not extend to the tip of the pointed posterior end. **b.** Adults removed from the heart of an infected dog. Note the threadlike appearance, which is typical of filarial worms. Cardiac and pulmonary pathology occurs in heavily infected dogs. In humans, worms die before attaining adulthood, and are washed into the lung microcirculation, where they form granulomas.


a
b
10 µm
c
20 µm
8.1

8.12 Microfilariae in peripheral blood smears, Giemsa stain. **a.** Microfilaria of *Brugia malayi*. **b.** Microfilaria of *Wuchereria bancrofti*. **c.** Microfilaria of *Loa loa*. These species are distinguished by the following criteria: presence of a terminal and subterminal nucleus in the tail of *B. malayi* (black arrows), separated by an indentation, vs. the absence of nuclei in the tail of *W. bancrofti* (region enclosed by green bracket) vs. nuclei in the tail of *L. loa*; large cephalic space in *B. malayi* vs. small cephalic space in *W. bancrofti* (region enclosed by red bracket) and *L. loa*; compact column of nuclei in *B. malayi* and *L. loa* vs. more dispersed nuclei in *W. bancrofti*; and a stained sheath in *W. bancrofti* and *B. malayi*, vs. unstained sheath in *L. loa* (red arrows).

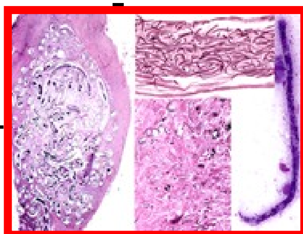
8.12a,b from J.T. Sullivan, *Electronic Atlas of Parasitology, 1.0.* Copyright © 1999 McGraw-Hill, Inc., Dubuque, IA. Reprinted by permission.

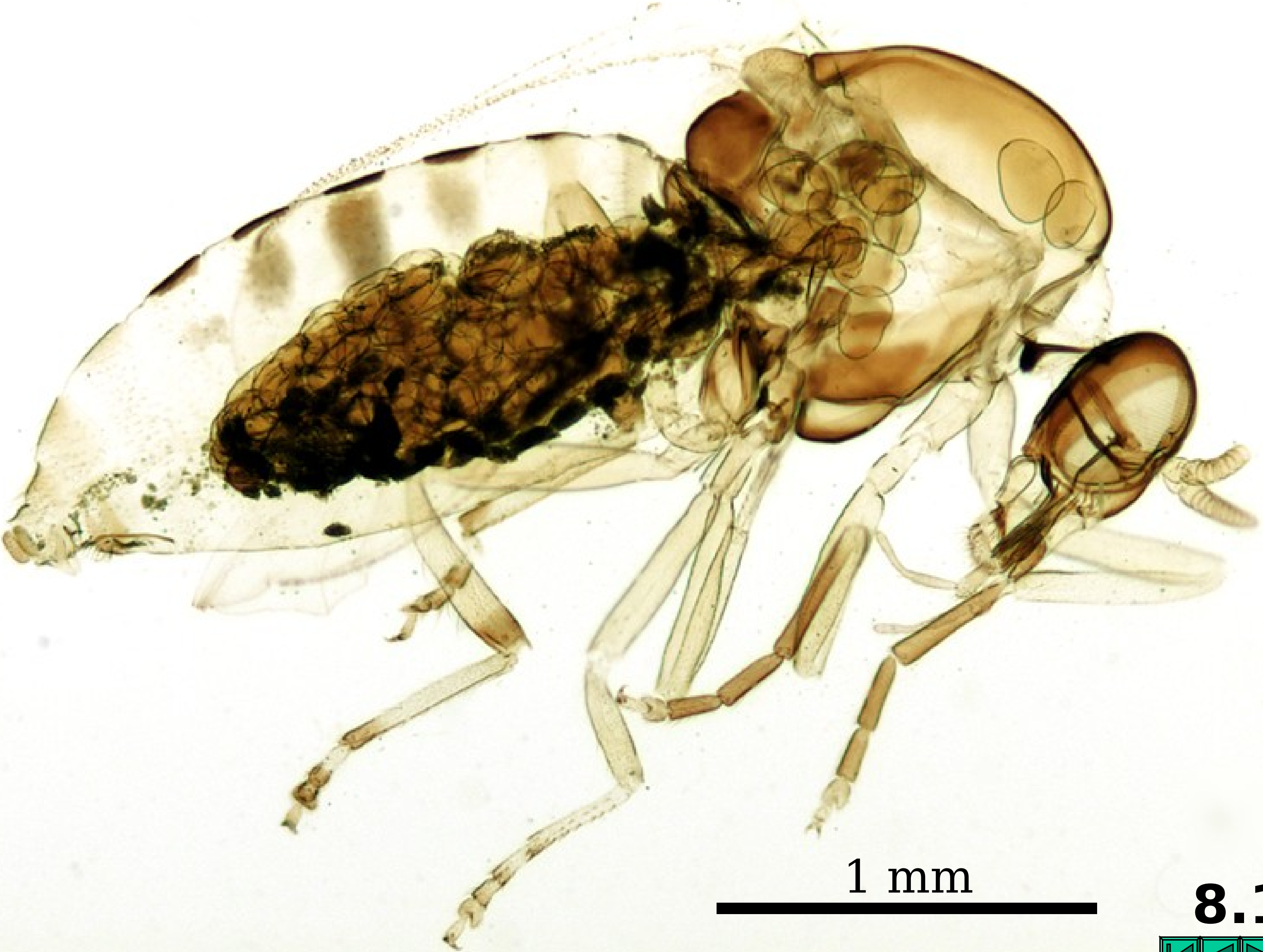
W. bancrofti
B.
layi
L. loa


a
1 mm
b
50 μm
c
50 μm
d
50 μm

8.1

8.13 *Onchocerca volvulus.* **a.** Histological section of adults in a fibrous capsule below the skin. These nodules develop at sites where infected black flies have bitten. **b.** Histological section of uterus of female, showing microfilariae. **c.** Histological section of dermis, showing wandering microfilariae (arrows). **d.** Microfilaria in a smear of a nodule. These microfilariae lack a sheath, have a very short cephalic space, nuclei that do not extend into the tip of the tail, and in some specimens a curved tail tip (arrow). Due to the inflammatory response against the microfilariae in the skin and eyes, severe dermatitis and blindness (“river blindness”) result from longstanding heavy infections. Human infections occur in Africa and South America, are transmitted by *Simulium* spp., the black fl

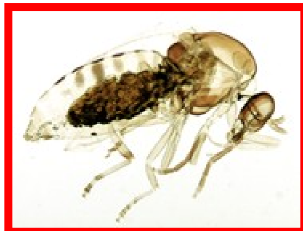


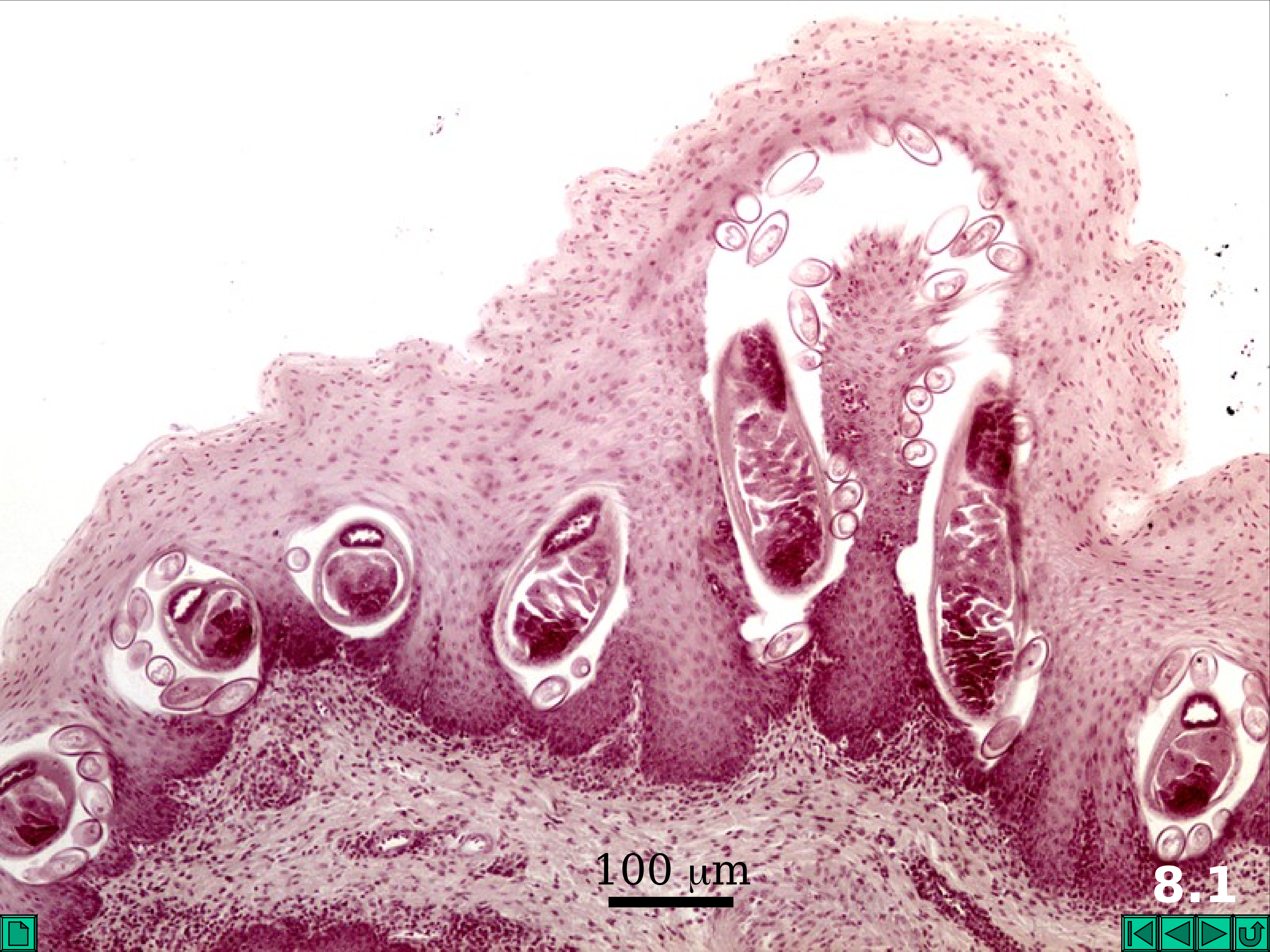


8.1

8.14 *Simulium* sp. (black fly), the vector of *Onchocerca volvulus*. Note humped appearance of the thorax. These insects lay their eggs in fast-flowing, oxygenated water. As a result, transmission of onchocerciasis occurs in the vicinity of rivers and streams, hence the name of the disease, "river blindness."

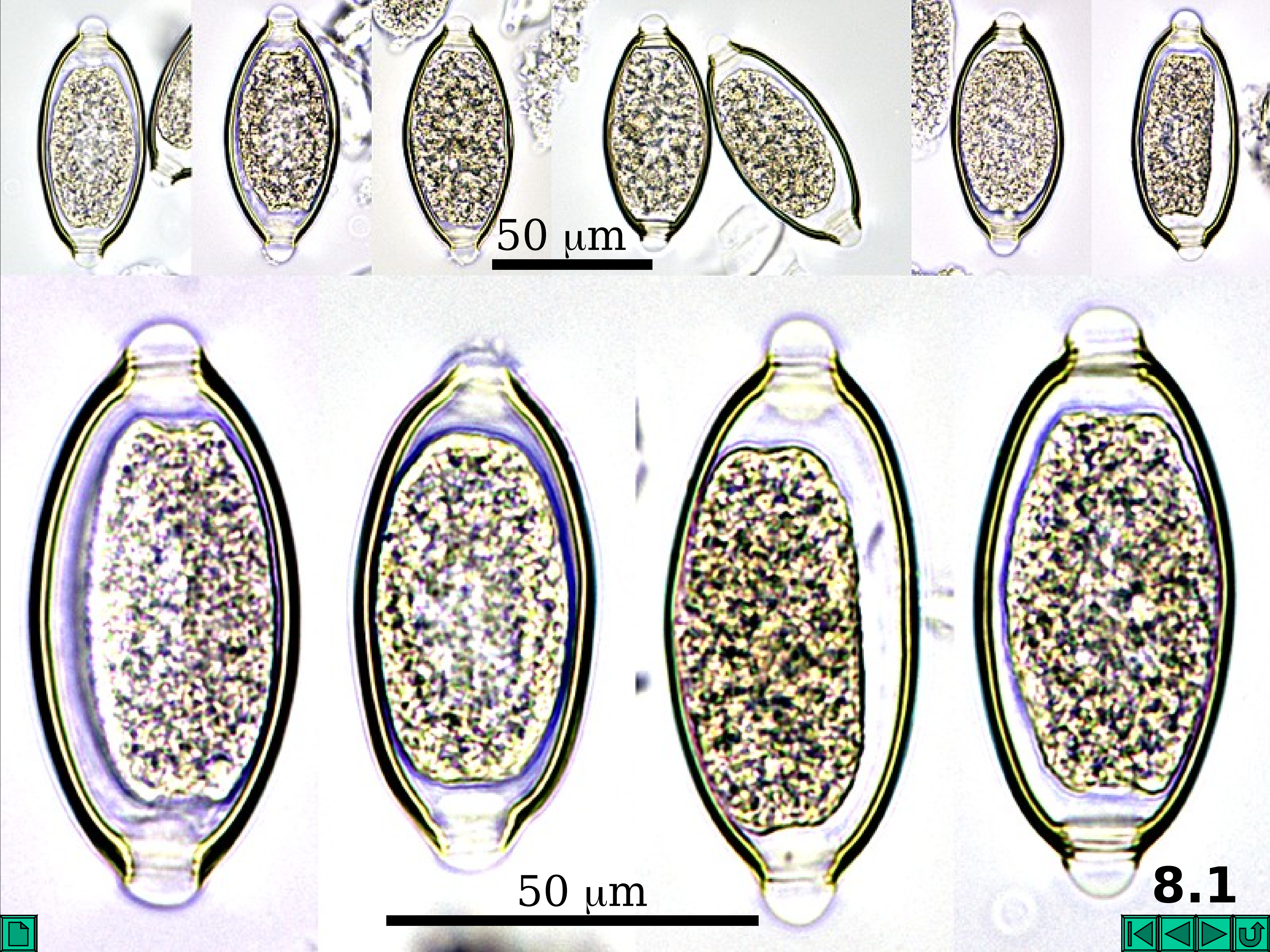
- back to *Onchocerca volvulus*





8.1

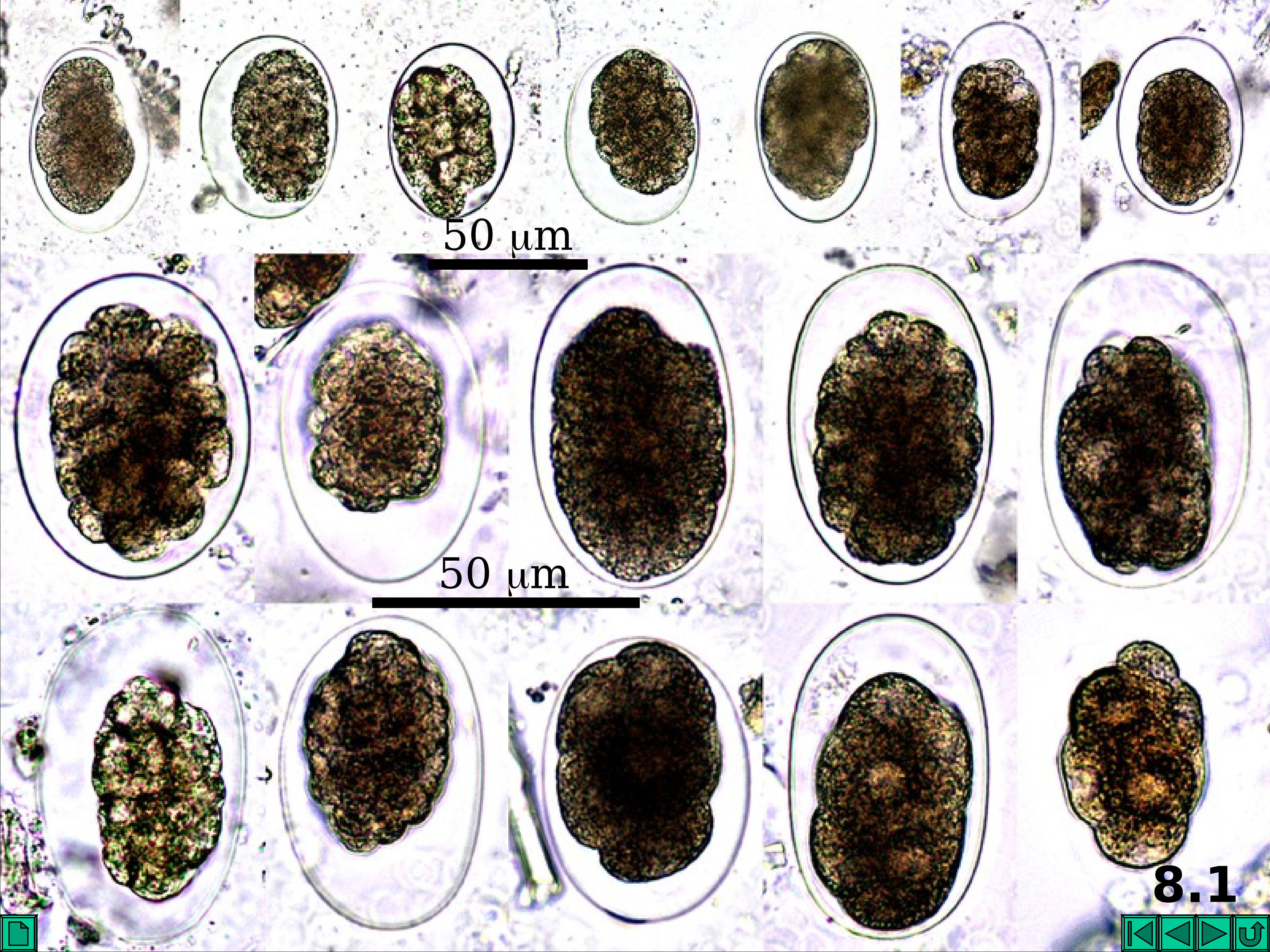
8.15 *Gongylonema ingluvicola* in esophageal epithelium of a pig. The worm tunnels through the epithelium, leaving trails of eggs which are shed into the lumen, swallowed, and passed out in the feces. Infection results from ingesting insect intermediate hosts (cockroaches and dung beetles) containing infective L_3 larvae.



8.1

8.16 Eggs of *Trichuris trichiura.* Top row is at same magnification as trematode eggs in Chapter 6. Note the symmetrical barrel shape and plugs on each end. Embryonation to the infective L_1 requires approximately two weeks.

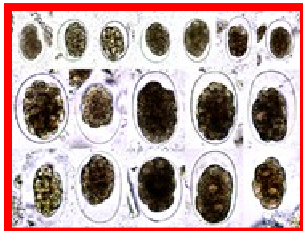
- back to adult of *Trichuris trichiura*
- back to *Capillaria hepatica*

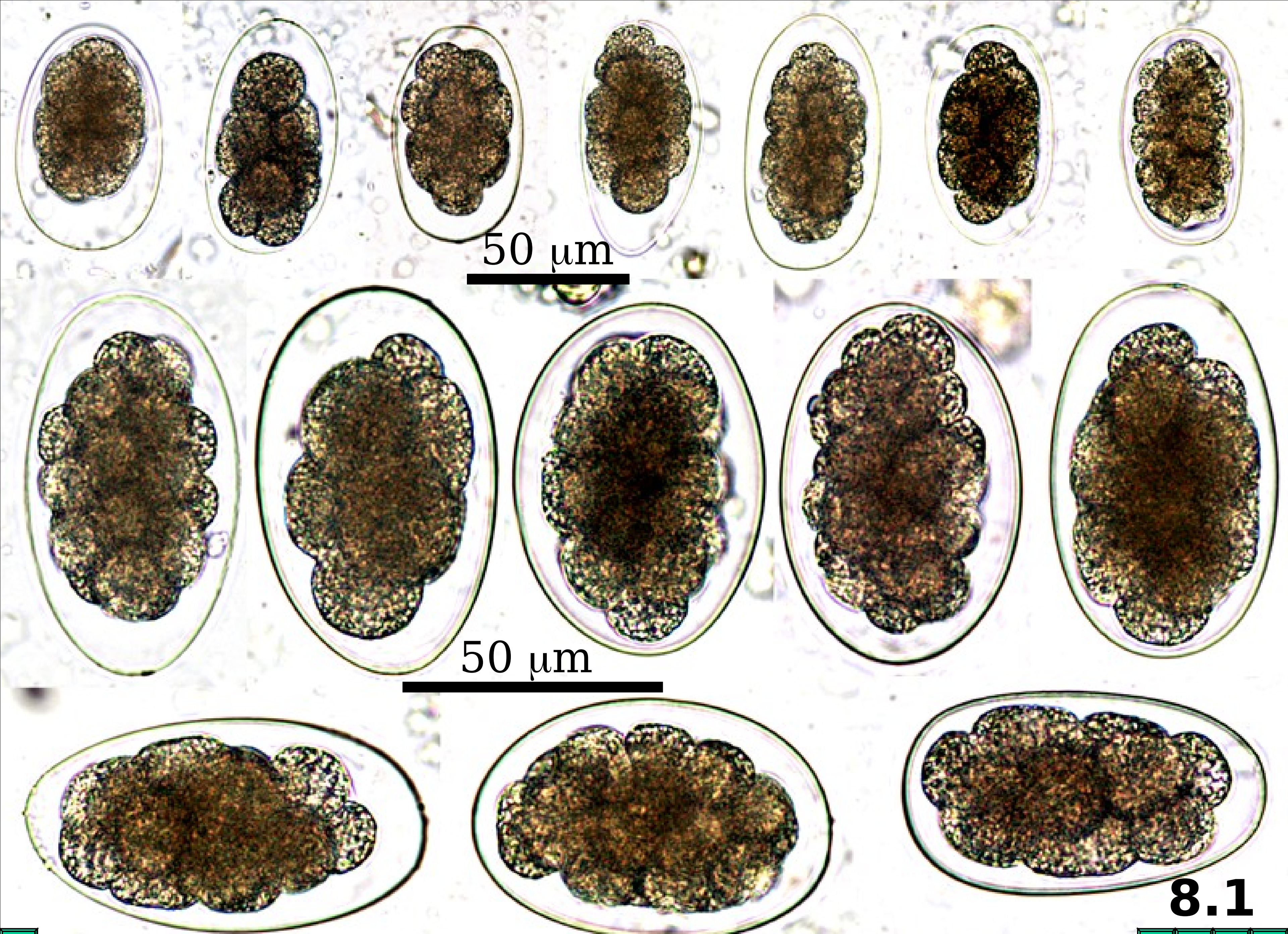

50 µm
50 µm

8.17 Hookworm eggs (*Necator americanus*). Top row is at same magnification as trematode eggs in Chapter 6. The embryo is surrounded by an extremely thin shell, which sometimes collapses or is stripped off during specimen preparation (bottom right photograph). Eggs of the two major human-infecting hookworms, *Necator americanus* and *Ancylostoma duodenale*, are indistinguishable. Embryos are usually at the 4 or 8-cell stage when eggs are passed out in the feces.

- back to eggs of *Trichostrongylus* spp.

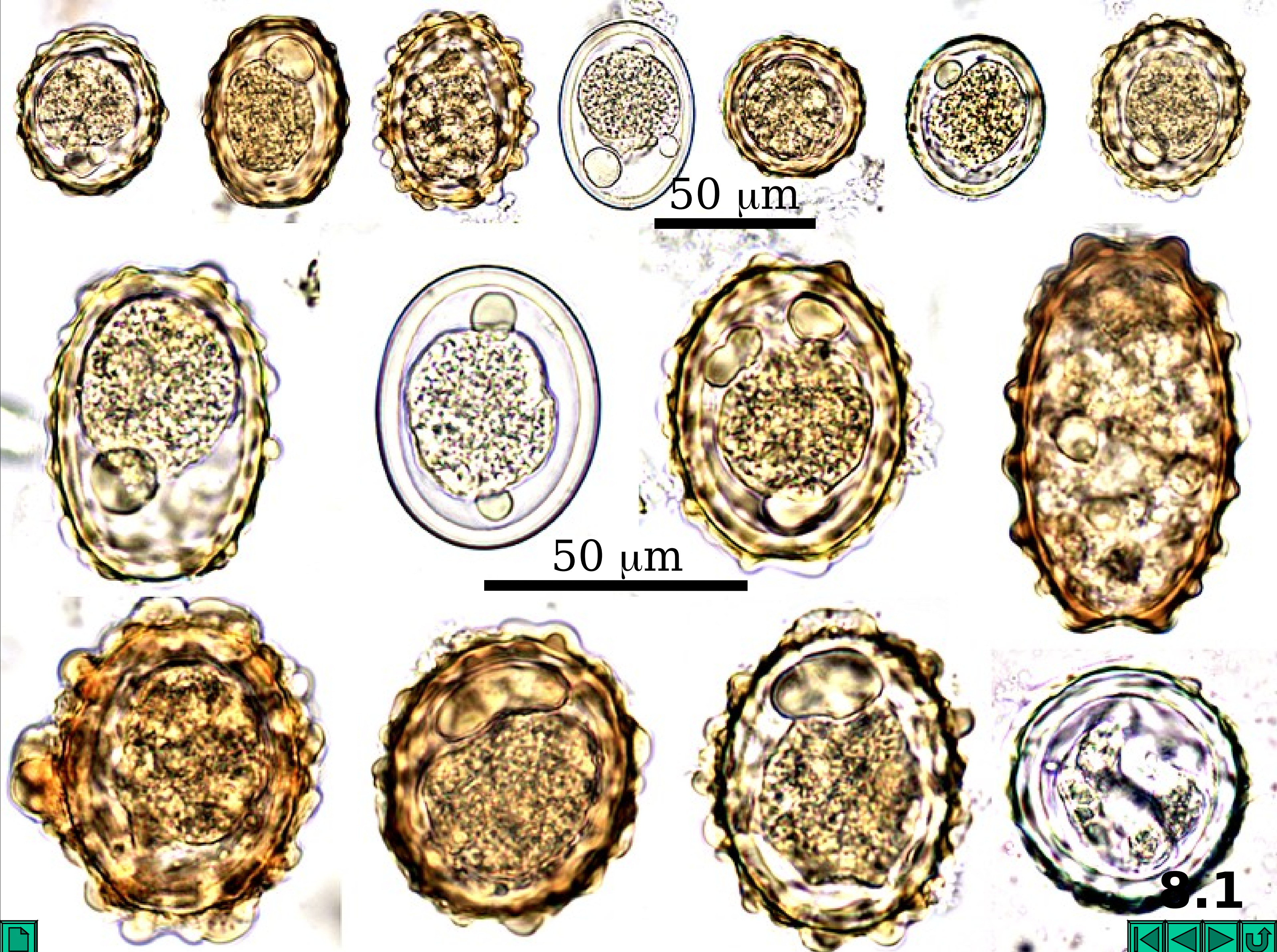
- back to eggs of *Ascaris lumbricoides*





8.1

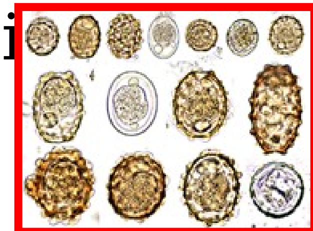
8.18 Eggs of *Trichostrongylus* spp. Top row is at same magnification as trematode eggs in Chapter 6. Eggs of these blood-sucking intestinal nematodes appear similar to those of hookworms, with a thin shell and morula embryo. However, they are larger, one end is more tapered, and the embryo contains a greater number of cells.

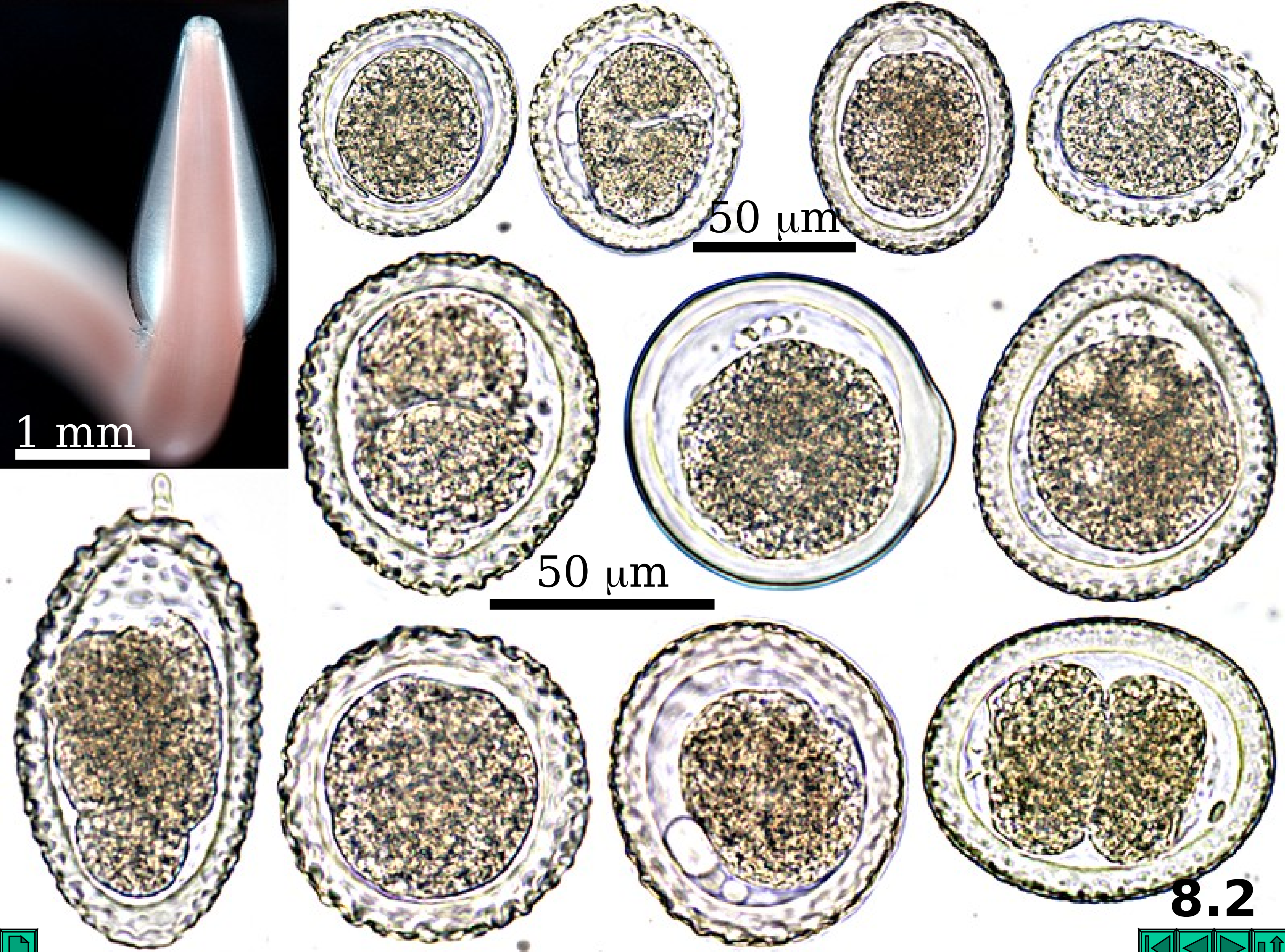

50 µm
50 µm

8.19 Eggs of *Ascaris lumbricoides*. Top row is at same magnification as trematode eggs in Chapter 6. The outermost layer of the shell is proteinaceous and mammillated (bumpy). The eggs typically contain an uncleaved embryo (zygote) when passed in the feces, and the embryo develops to the L_2 (bottom right photo) in 9-13 days. The eggs are extraordinarily resistant to adverse environmental conditions, and can survive for 10 years in shaded soil. Eggs sometimes are decorticated, i.e., without the mammillated coat, and consequently appear smooth surfaced. These can be distinguished from hookworm eggs by their thick shell. Unfertilized eggs also are found; these are more elongate than the fertilized eggs, and do not contain a spherical embryo (last photo, mi

row).

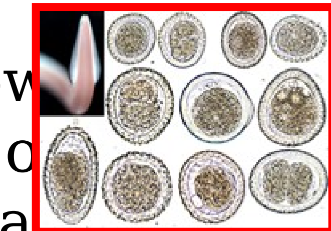
- back to adult of *Ascaris lumbricoides*
- back to eggs of *Toxocara canis*

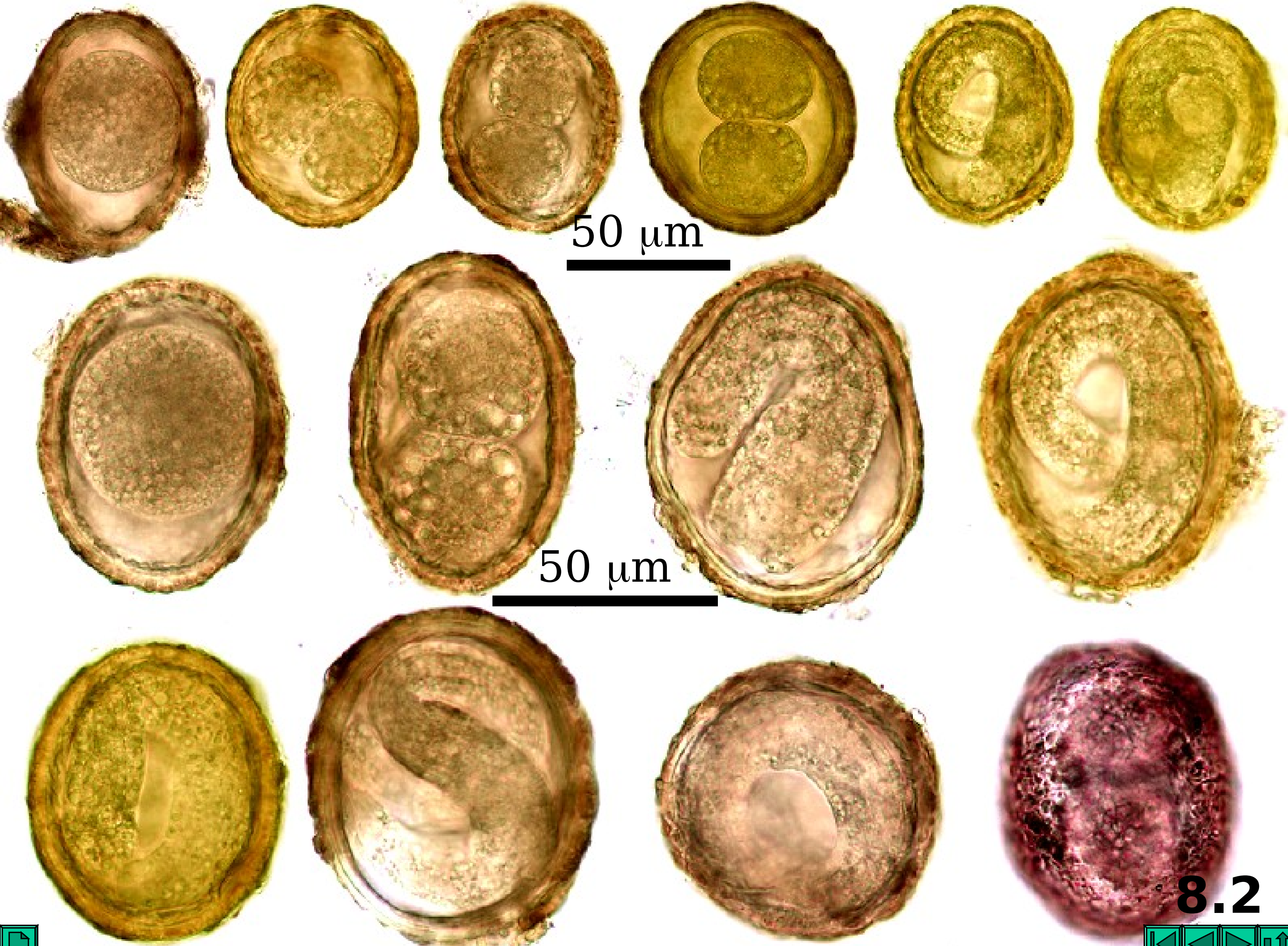



1 mm
50 µm
50 µm

8.20 Eggs of *Toxocara canis*. Top row is at same magnification as trematode eggs in Chapter 6. This ascarid parasite infects dogs and has a life cycle similar to that of *Ascaris lumbricoides*. Infection occurs when an egg containing the L_2 is ingested. Although not capable of developing to the adult stage in humans, its larvae wander in the visceral tissues of persons accidentally ingesting the infective egg, causing the condition known as visceral larva migrans. Many larvae become encapsulated in the liver, causing minimal symptoms (fever, eosinophilia), but those wandering into the brain or eye can cause disease. Because the parasite is capable of transplacental infection, most puppies are born infected and therefore are quite hazardous until dewormed. A related species, *T. cati*, infects cats, but is not capable of transplacental infection. Both species have cervical alae, shown in the upper row *T. cati*. As do eggs of *Ascaris lumbricoides*, eggs o *Toxocara* can survive for years in the soil, and ma

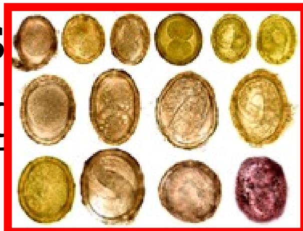
- back to eggs of *Baylisascaris procyonis*

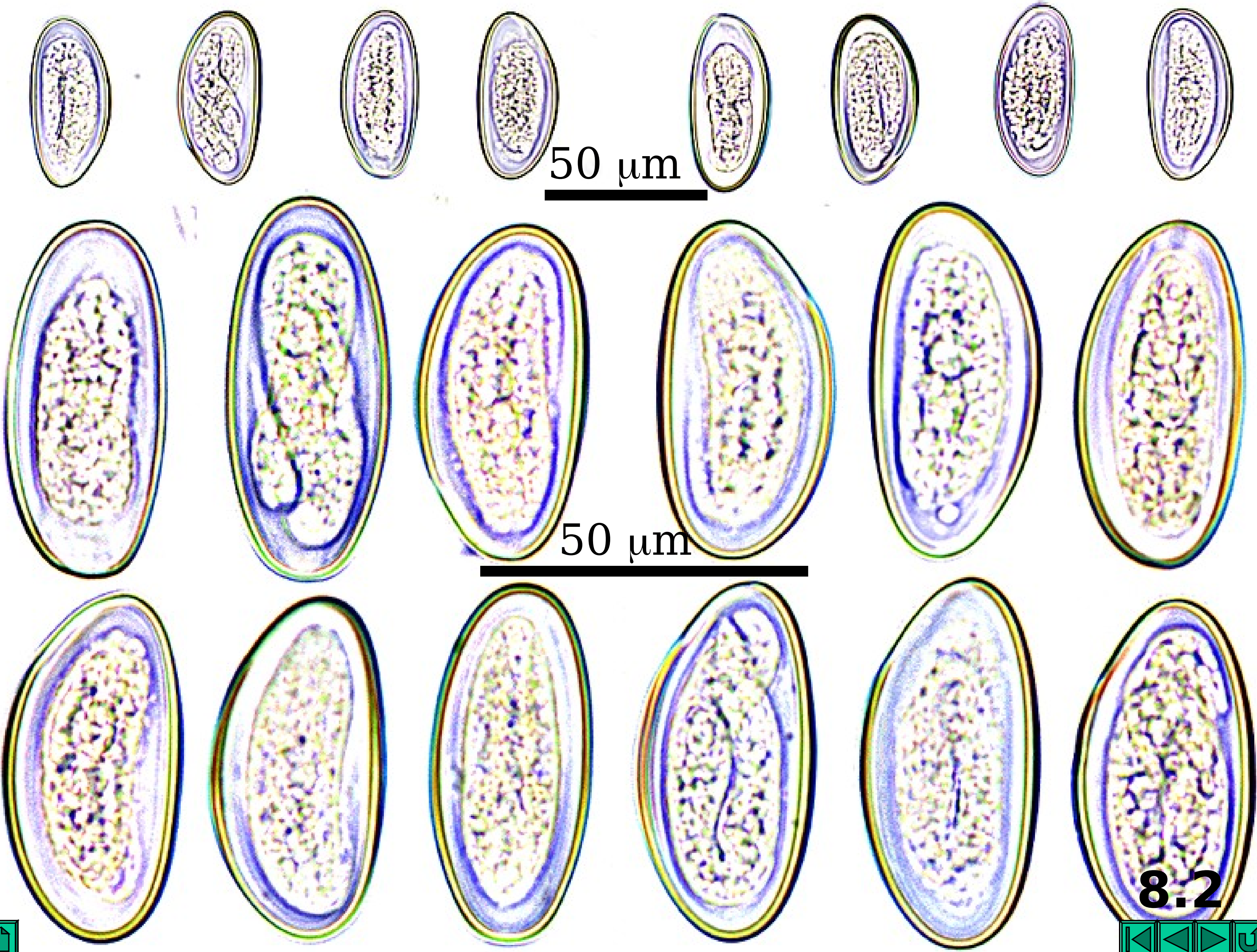




8.2

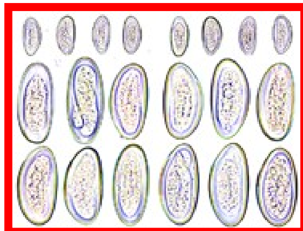
8.21 Eggs of *Baylisascaris procyonis*. Top row is at same magnification as trematode eggs in Chapter 6. This ascarid parasite infects raccoons and has a life cycle similar to that of *Ascaris lumbricoides*. Infection occurs when an egg containing the L_2 is ingested. Although not capable of developing to the adult stage in humans, its larvae wander in the visceral tissues of persons accidentally ingesting the infective egg, causing the condition known as visceral larva migrans (which can also be due to *Toxocara* spp.). The larva of *B. procyonis* has a tendency to invade the central nervous system, causing severe disease (neural larva migrans), especially in children. *B. procyonis* has been responsible for several human fatalities in the U.S., as well as outbreaks of fatal neural larva migrans among wild and domesticated animals. Bottom right

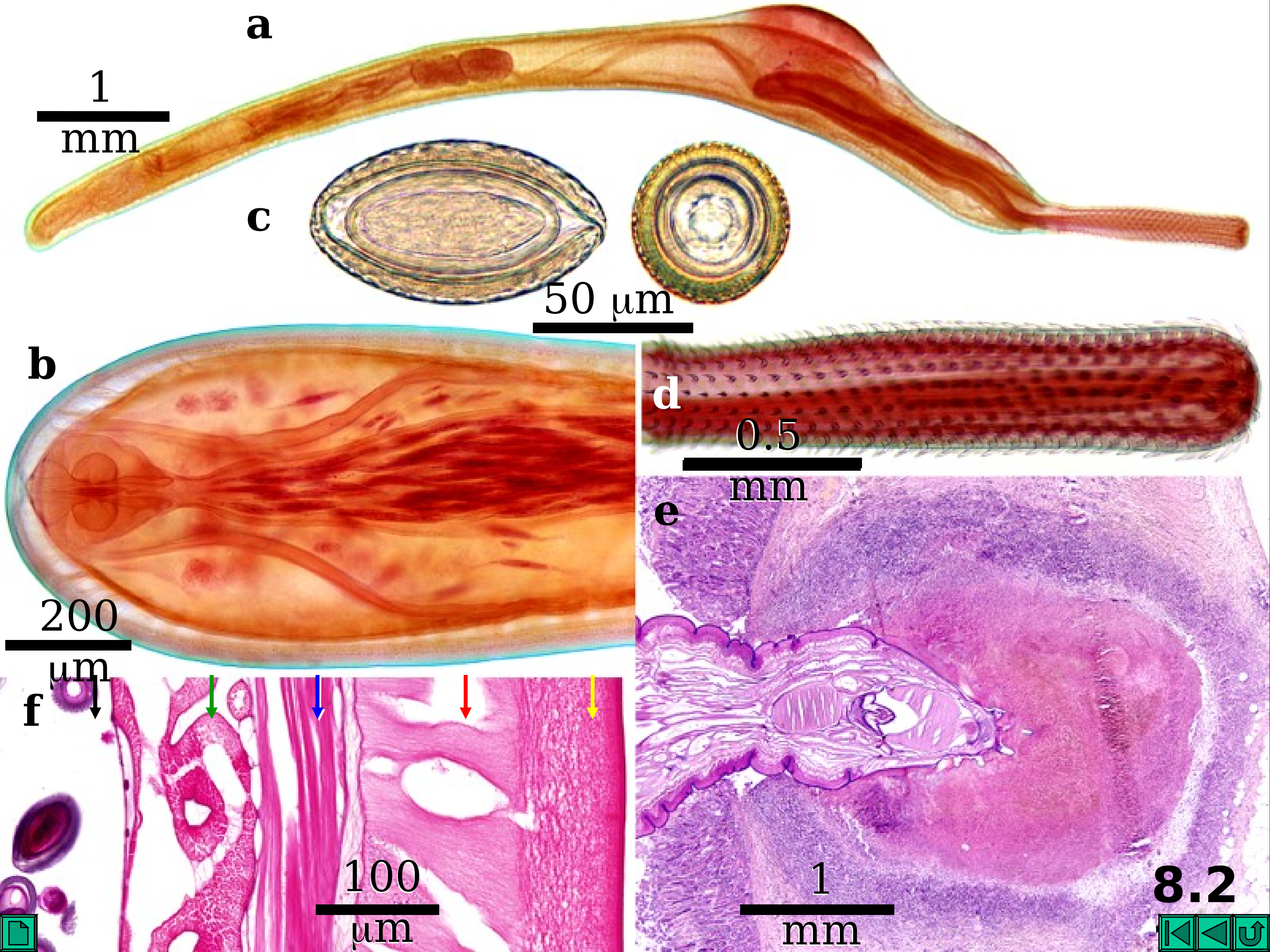



50 µm
50 µm

8.22 Eggs of *Enterobius vermicularis*. Top row is at same magnification as trematode eggs in Chapter 6. These eggs are deposited on the perianal skin by the female at night, and embryonate to the infective L_3 stage within 6 hours. Eggs soon contaminate bed sheets, clothing, and, because they are easily lifted aloft in air currents, the surrounding room. When viewed on edge, the eggs appear flat on one side.

- back to adult of *Enterobius vermicularis*

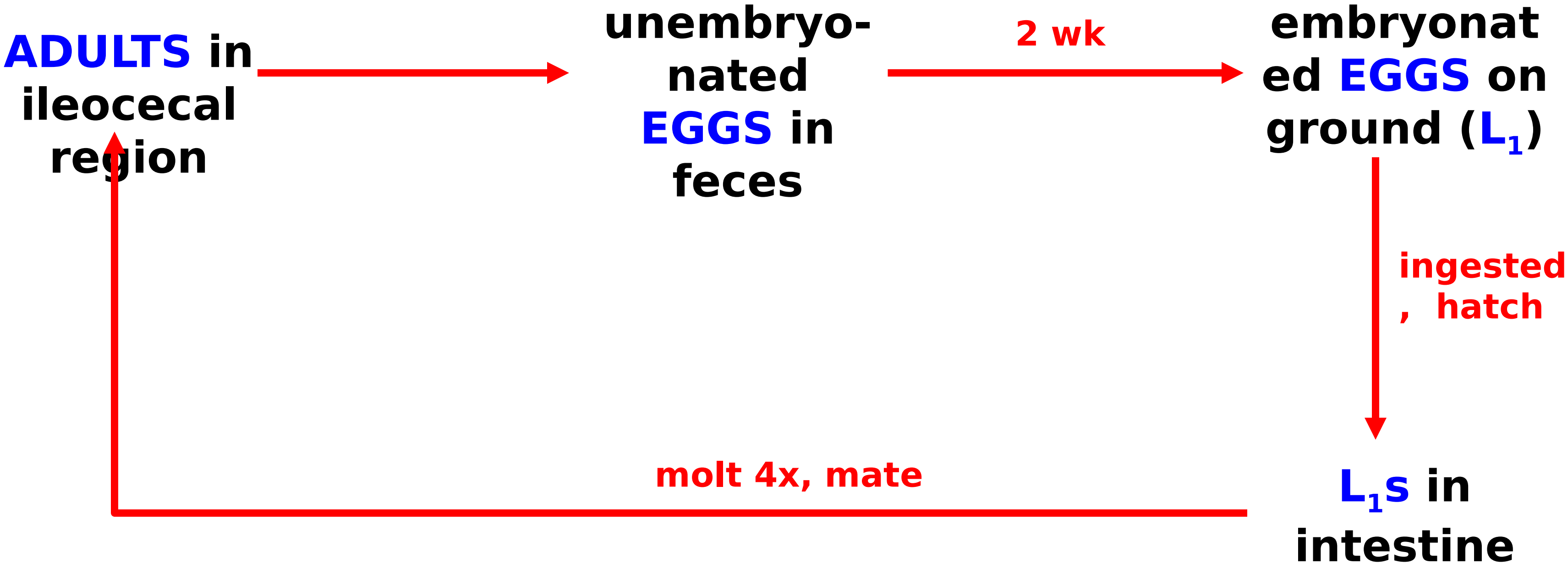



a
1 mm
c
50 μm
b
200 μm
d
0.5 mm
e
1 mm
f
100 μm

8.2

8.23 Acanthocephalans. These worms bear some similarity to nematodes in that they are pseudocoelomates, yet also show affinities with tapeworms in having no digestive tract and possessing a tegument rather than a cuticle. The defining feature is the spiny proboscis. **a.** Adult male acanthocephalan. Note the extended proboscis, proboscis receptacle, and 2 testes within a ligament sac at mid body. **b.** Posterior end of female, showing uterus containing eggs. **c.** Egg of *Macracanthorhynchus hirudinaceous* viewed on end and lengthwise. The embryo (acanthor) is surrounded by several membranes. **d.** Proboscis from female worm in **b.** **e.** Histological section of *M. hirudinaceous* nearly perforating the intestinal wall. Infections occur in humans who ingest insects harboring the infective larval stage (cystacanth). **f.** Histological cross section of the body wall of a female *M. hirudinaceous*. The tegument has a relatively homogeneous outer layer (yellow arrow) and an underlying radial fiber zone arrow), in which are found longitudinal spaces cal lacunae. A layer of circular (blue arrow) and longitudinal (green arrow) muscle lies below. Fin

Life cycle of *Trichuris trichiura*



ADULTS in ileocecal region

unembryonated EGGS in feces

2 wk

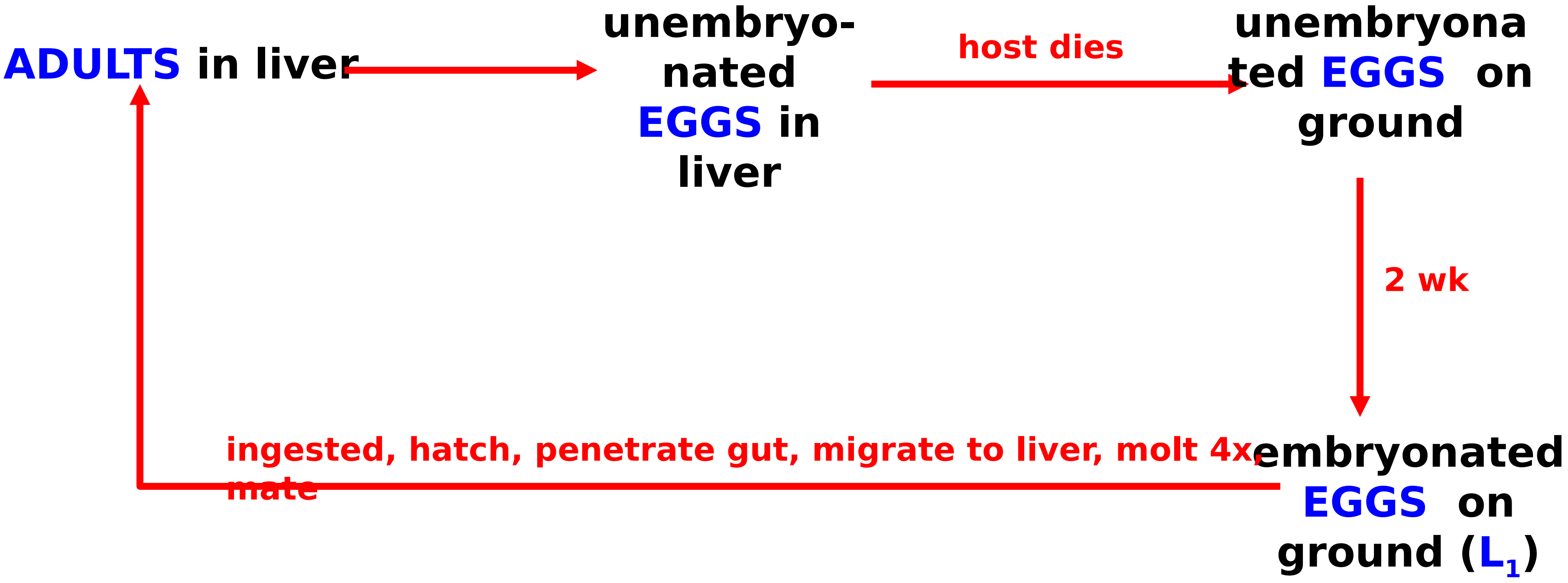
embryonated EGGS on ground (L$_1$)

ingested, hatch

L$_1$s in intestine

molt 4x, mate

Life cycle of *Capillaria hepatica*



ADULTS in liver

unembryonated **EGGS** in liver

host dies

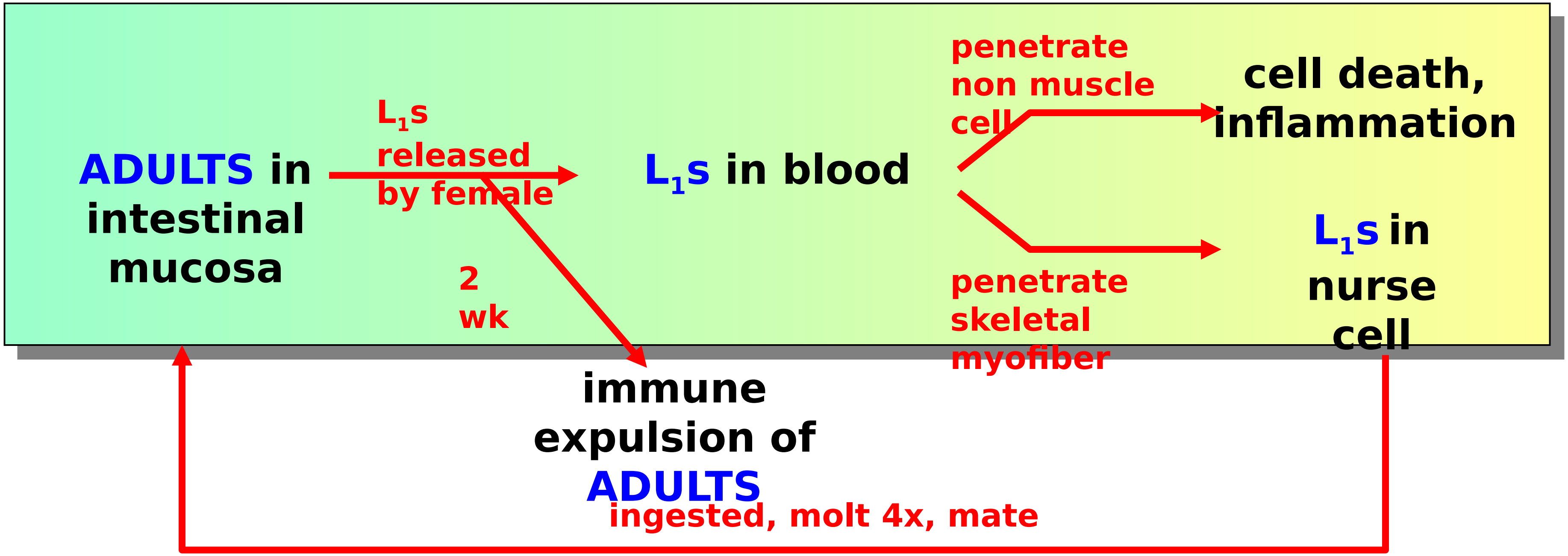
unembryonated **EGGS** on ground

2 wk

embryonated **EGGS** on ground (L_1)

ingested, hatch, penetrate gut, migrate to liver, molt 4x, mate

Life cycle of *Trichinella spiralis*



ADULTS in intestinal mucosa

L_1s released by female

2 wk

immune expulsion of **ADULTS**

L_1s in blood

penetrate non muscle cell

cell death, inflammation

penetrate skeletal myofiber

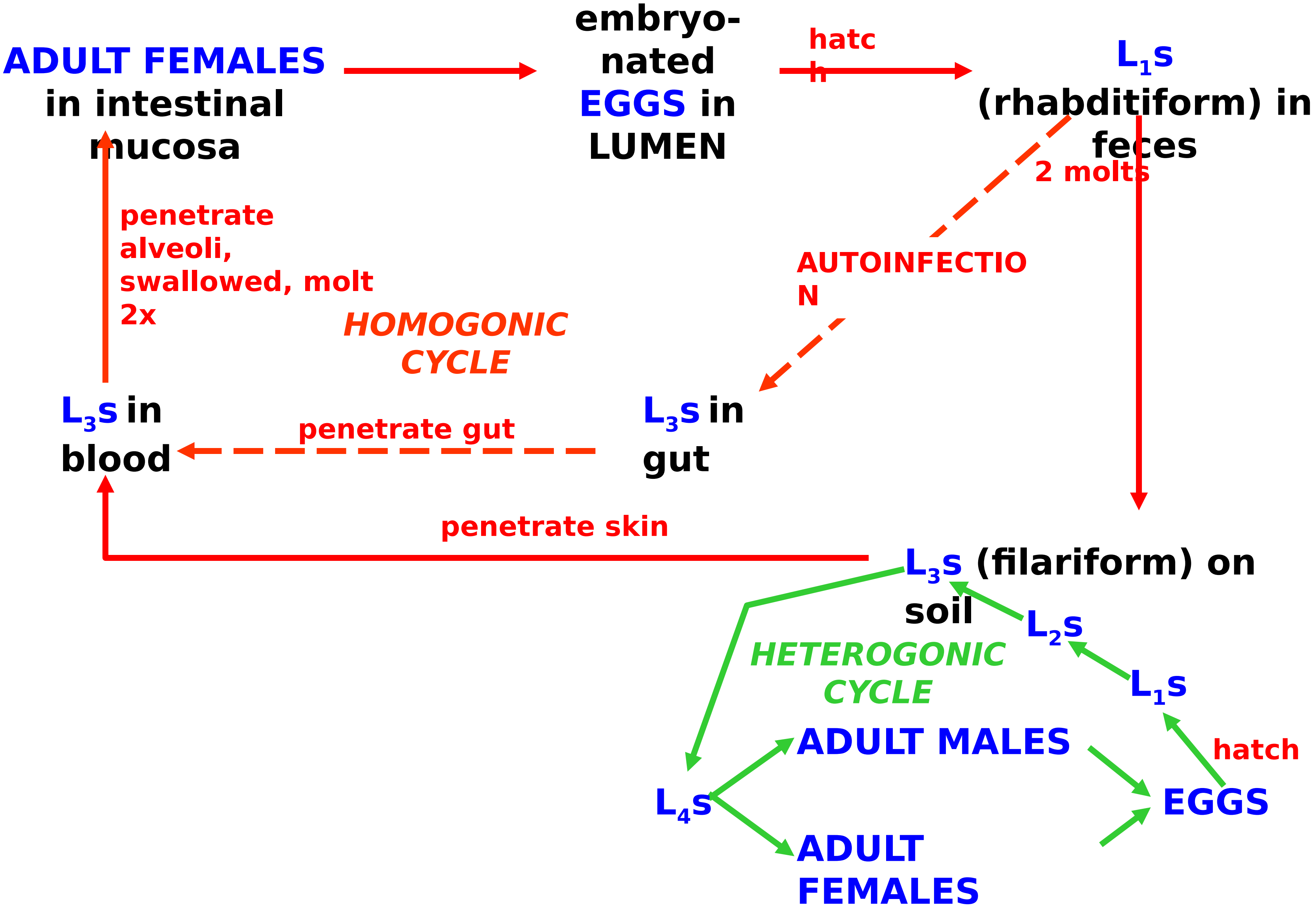
L_1s in nurse cell

ingested, molt 4x, mate

🟩 definitive host

🟨 intermediate host (=same individual as the definitive host)

Life cycle of *Strongyloides stercoralis*



ADULT FEMALES in intestinal mucosa

embryonated **EGGS** in LUMEN

hatch

L_1s (rhabditiform) in feces

2 molts

AUTOINFECTION

penetrate alveoli, swallowed, molt 2x

HOMOGONIC CYCLE

L_3s in blood

penetrate gut

L_3s in gut

penetrate skin

L_3s (filariform) on soil

L_2s

HETEROGONIC CYCLE

L_1s

hatch

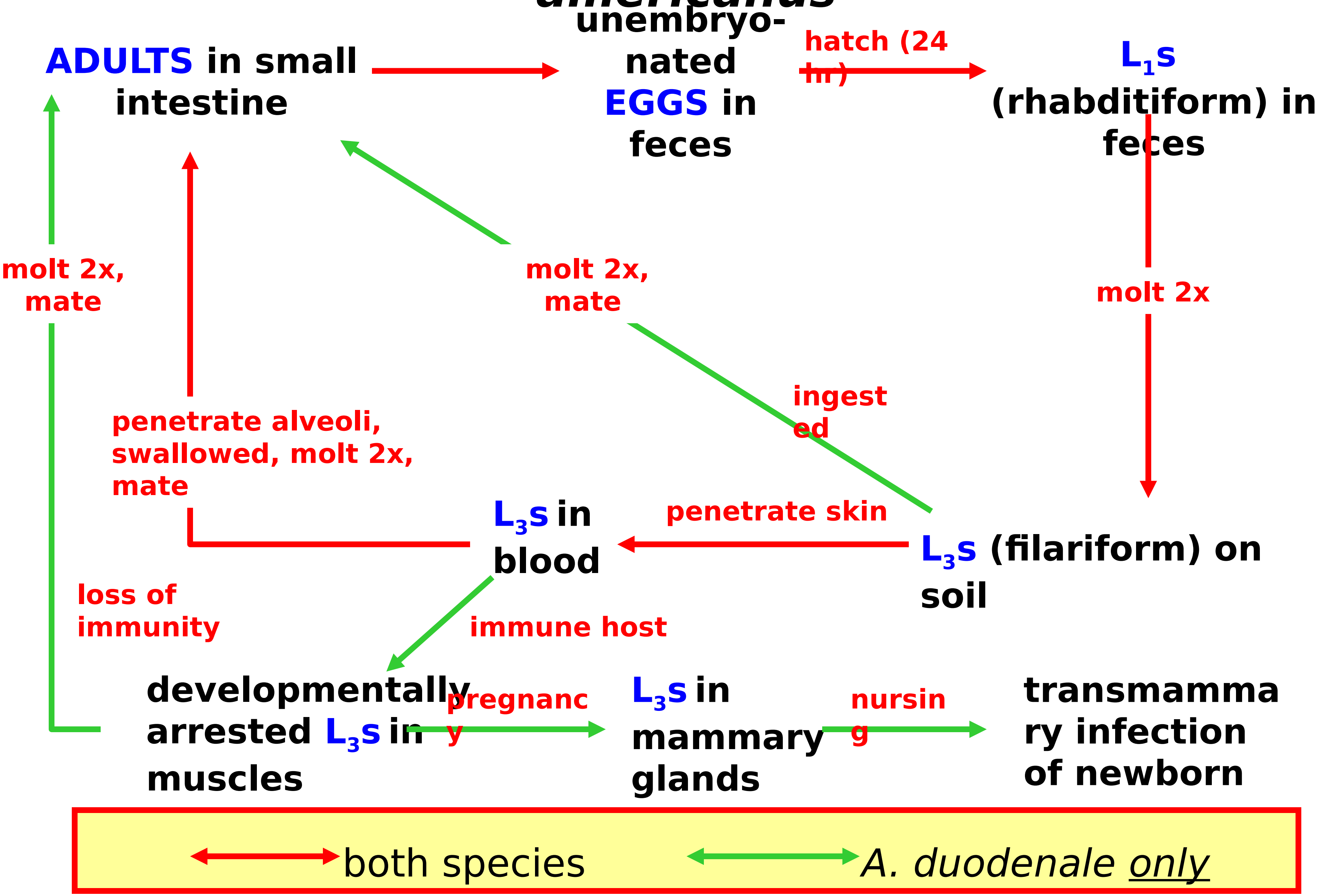
ADULT MALES

L_4s

EGGS

ADULT FEMALES

Life cycle of *Ancylostoma duodenale* & *Necator americanus*



ADULTS in small intestine

unembryonated EGGS in feces

hatch (24 hr)

L_1s (rhabditiform) in feces

molt 2x

L_3s (filariform) on soil

ingested

molt 2x, mate

penetrate skin

L_3s in blood

penetrate alveoli, swallowed, molt 2x, mate

immune host

developmentally arrested L_3s in muscles

loss of immunity

molt 2x, mate

pregnancy

L_3s in mammary glands

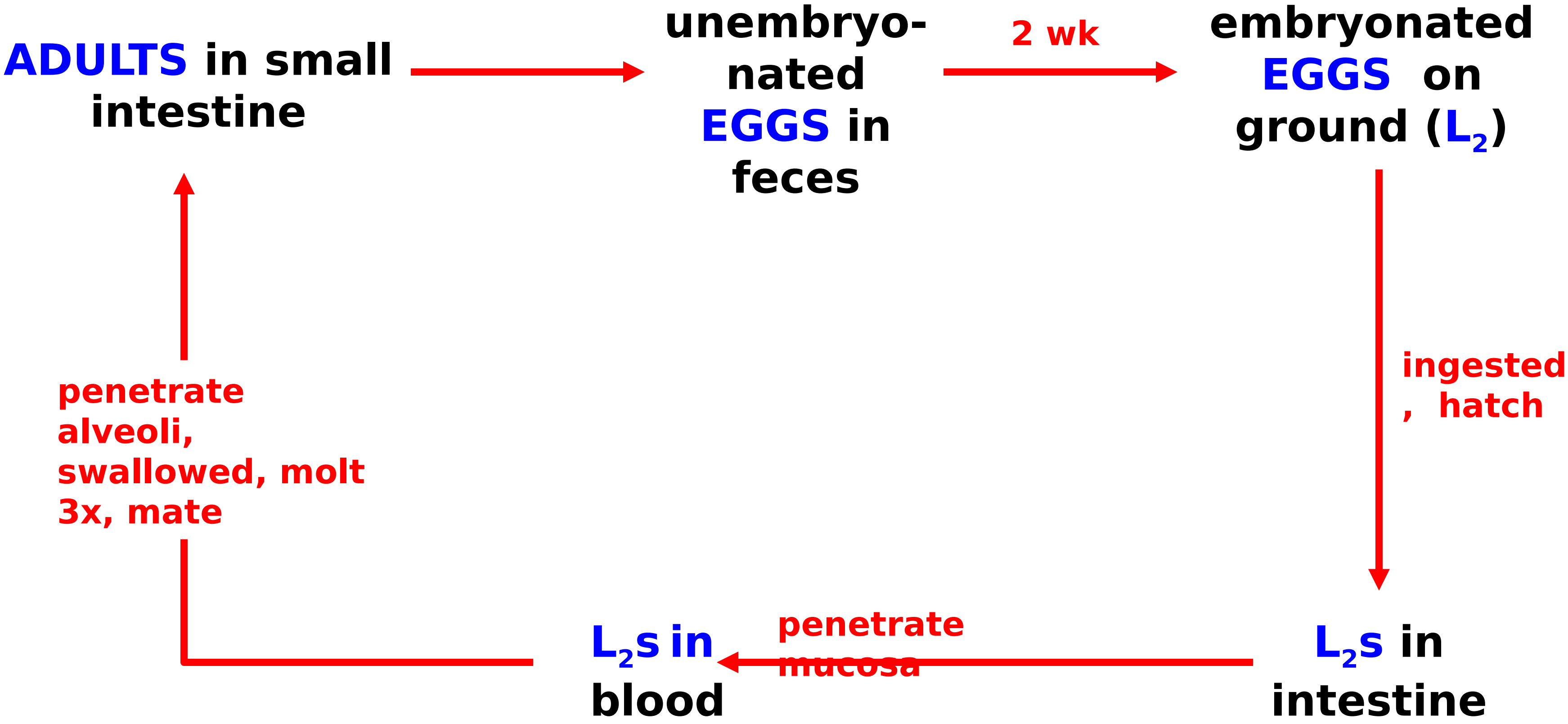
nursing

transmammary infection of newborn

↔ both species

↔ *A. duodenale* only

Life cycle of *Ascaris lumbricoides*



ADULTS in small intestine

unembryo-
nated
EGGS in
feces

2 wk

embryonated
EGGS on
ground (L_2)

ingested
, hatch

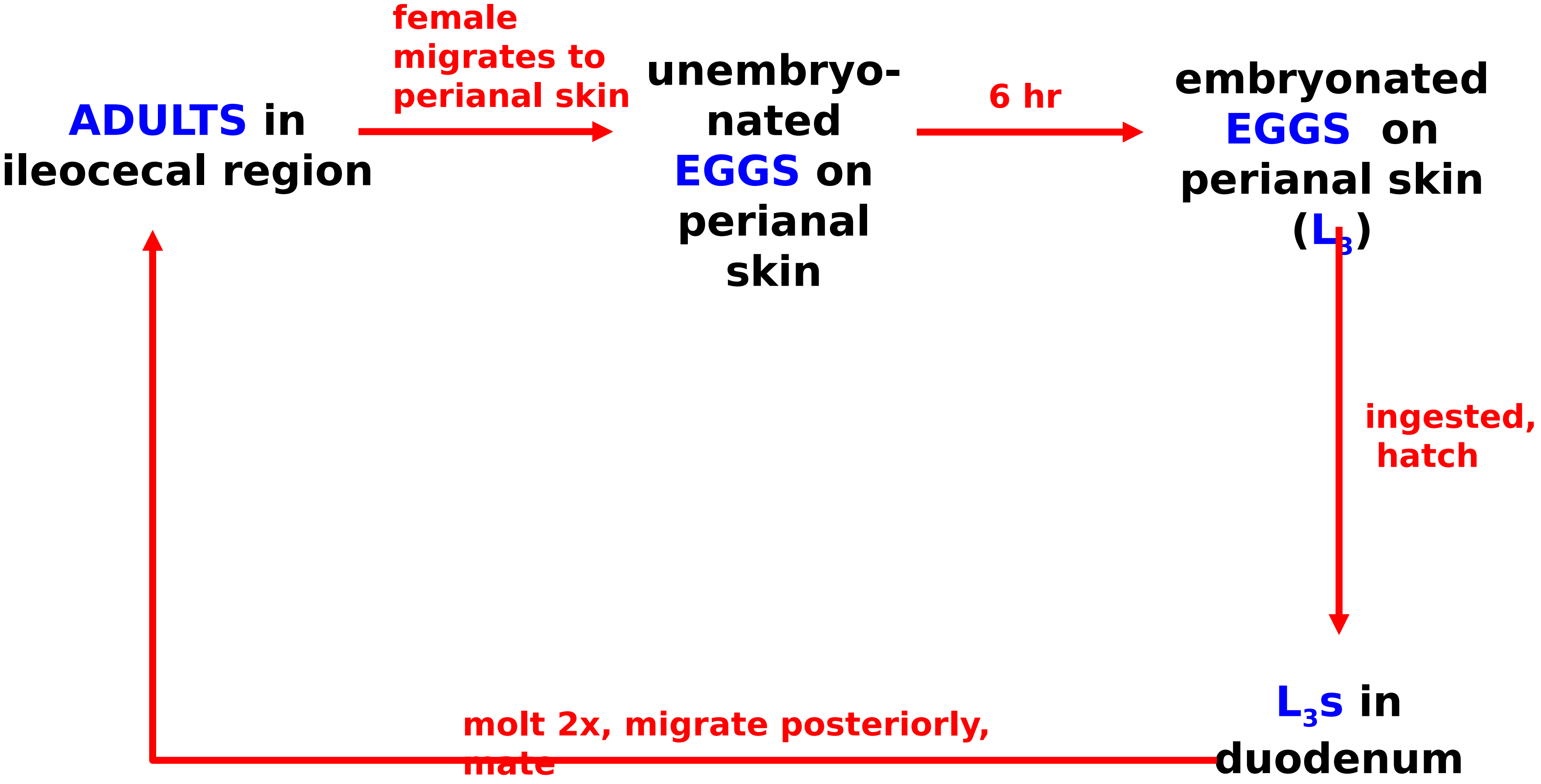
L_2s in
intestine

penetrate
mucosa

L_2s in
blood

penetrate
alveoli,
swallowed, molt
3x, mate

Life cycle of *Enterobius vermicularis*



ADULTS in ileocecal region

female migrates to perianal skin

unembryonated **EGGS** on perianal skin

6 hr

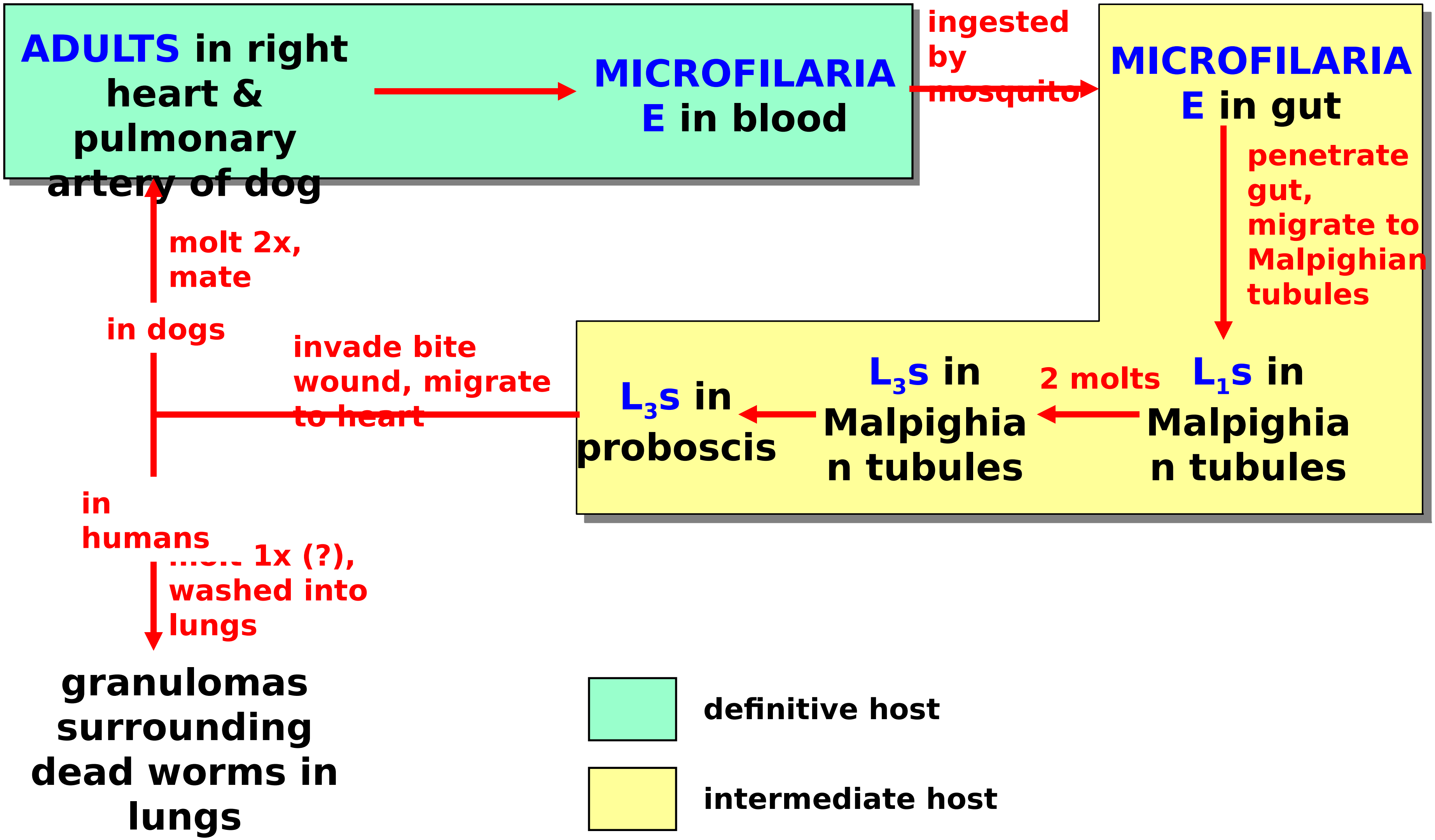
embryonated **EGGS** on perianal skin (L_3)

ingested, hatch

L_3s in duodenum

molt 2x, migrate posteriorly, mate

Life cycle of *Dirofilaria immitis*



ADULTS in right heart & pulmonary artery of dog

MICROFILARIAE in blood

ingested by mosquito

MICROFILARIAE in gut

penetrate gut, migrate to Malpighian tubules

L_1s in Malpighian tubules

2 molts

L_3s in Malpighian tubules

L_3s in proboscis

invade bite wound, migrate to heart

in dogs

molt 2x, mate

in humans

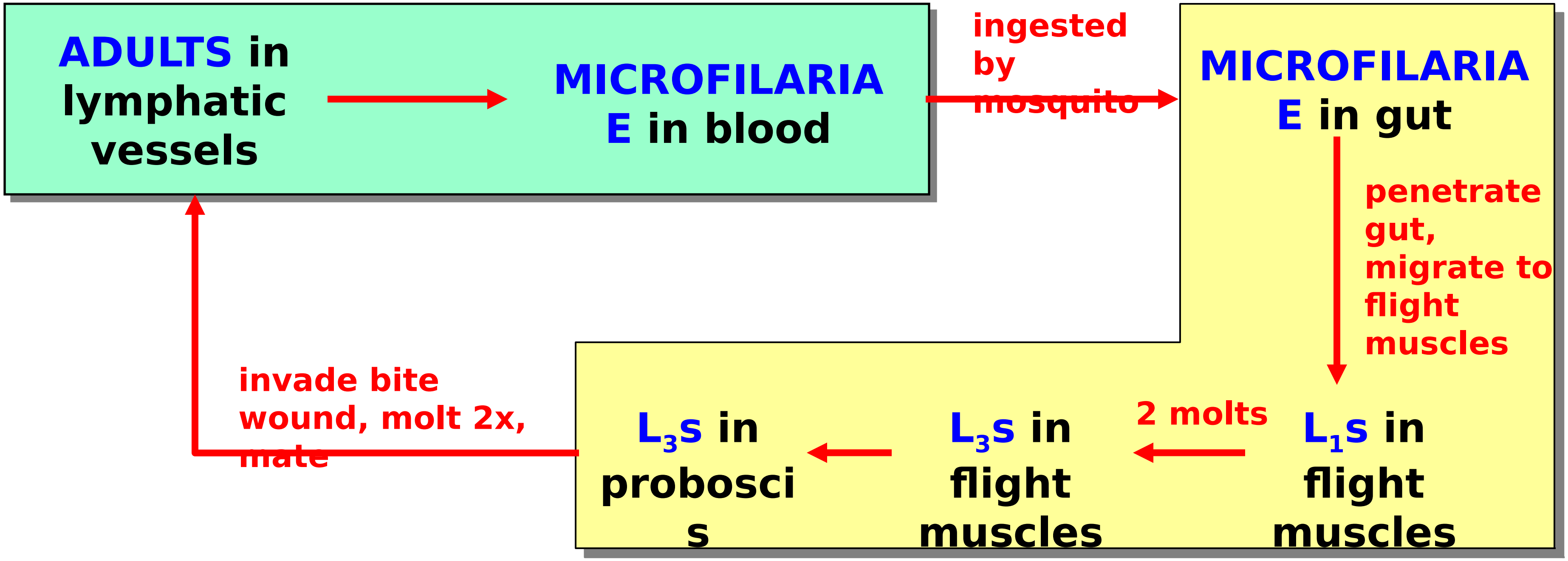
molt 1x (?), washed into lungs

granulomas surrounding dead worms in lungs

🟩 definitive host

🟨 intermediate host

Life cycle of *Wucheraria bancrofti & Brugia malayi*



ADULTS in lymphatic vessels

MICROFILARIAE in blood

ingested by mosquito

MICROFILARIAE in gut

penetrate gut, migrate to flight muscles

L_1s in flight muscles

2 molts

L_3s in flight muscles

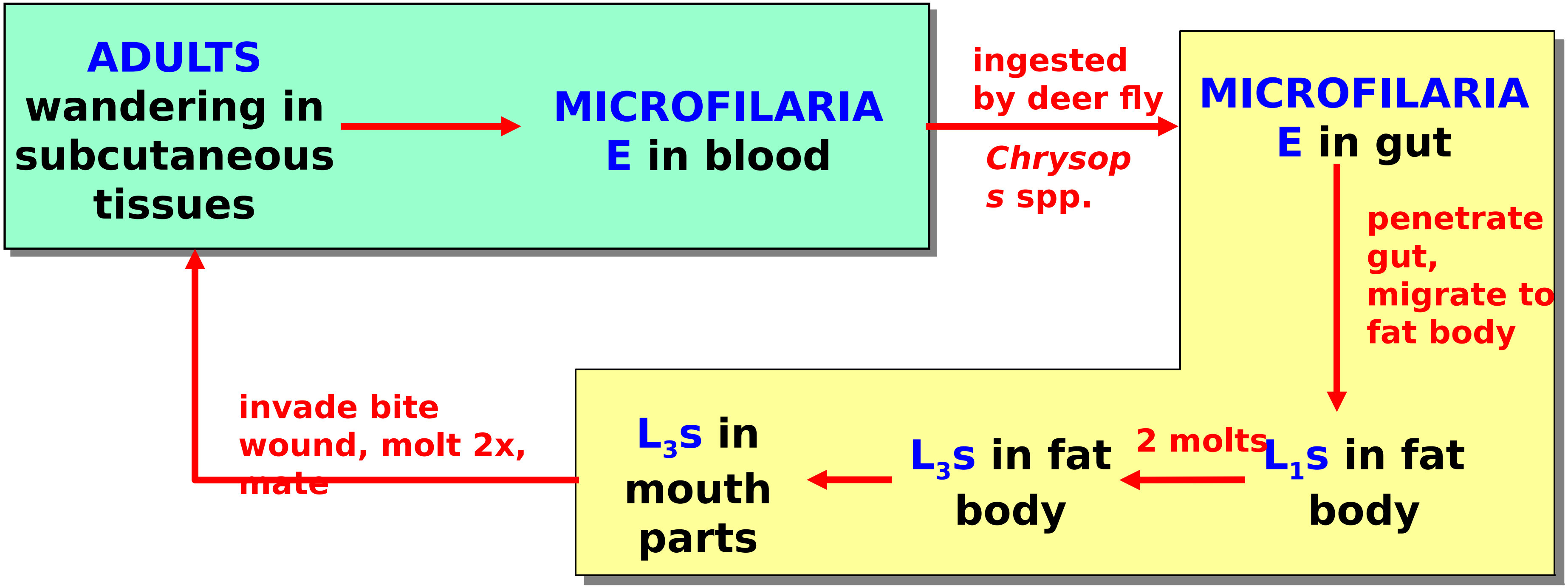
L_3s in proboscis

invade bite wound, molt 2x, mate

🟩 definitive host

🟨 intermediate host

Life cycle of *Loa loa*



ADULTS wandering in subcutaneous tissues

MICROFILARIAE in blood

ingested by deer fly *Chrysops* spp.

MICROFILARIAE in gut

penetrate gut, migrate to fat body

L_1s in fat body

2 molts

L_3s in fat body

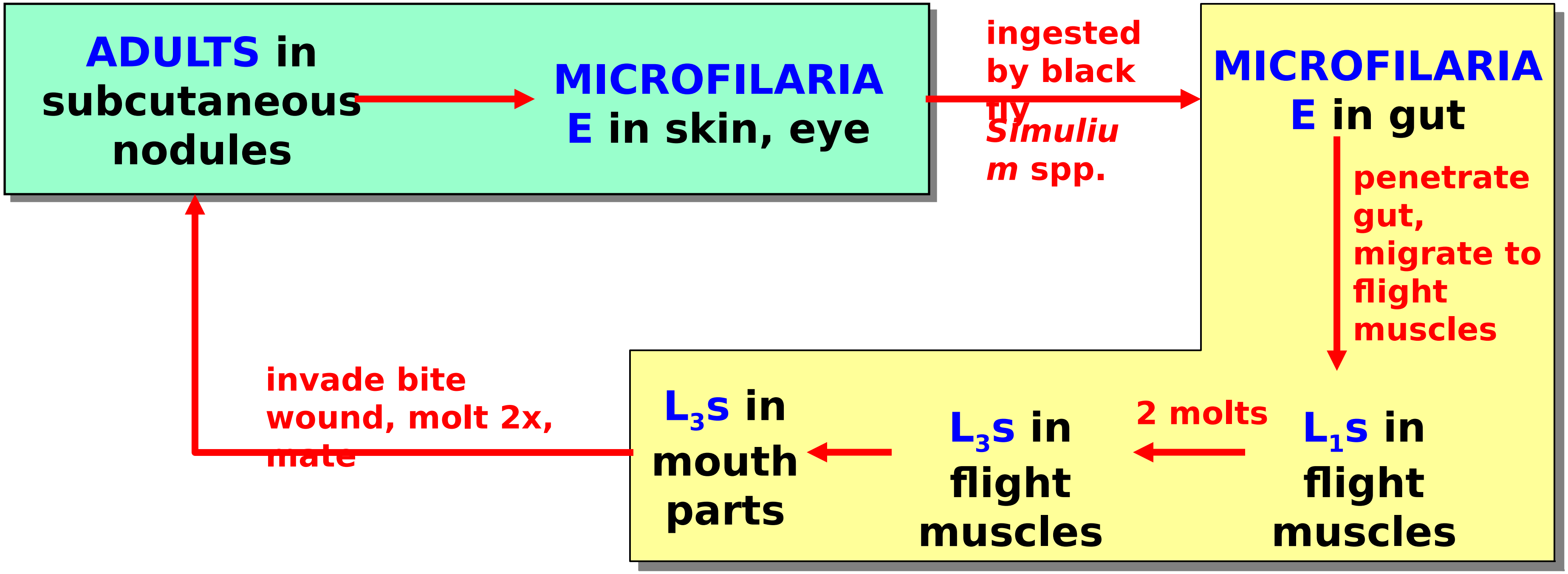
L_3s in mouth parts

invade bite wound, molt 2x, mate

🟩 definitive host

🟨 intermediate host

Life cycle of *Onchocerca volvulus*



ADULTS in subcutaneous nodules

MICROFILARIAE in skin, eye

ingested by black fly *Simulium* spp.

MICROFILARIAE in gut

penetrate gut, migrate to flight muscles

L_1s in flight muscles

2 molts

L_3s in flight muscles

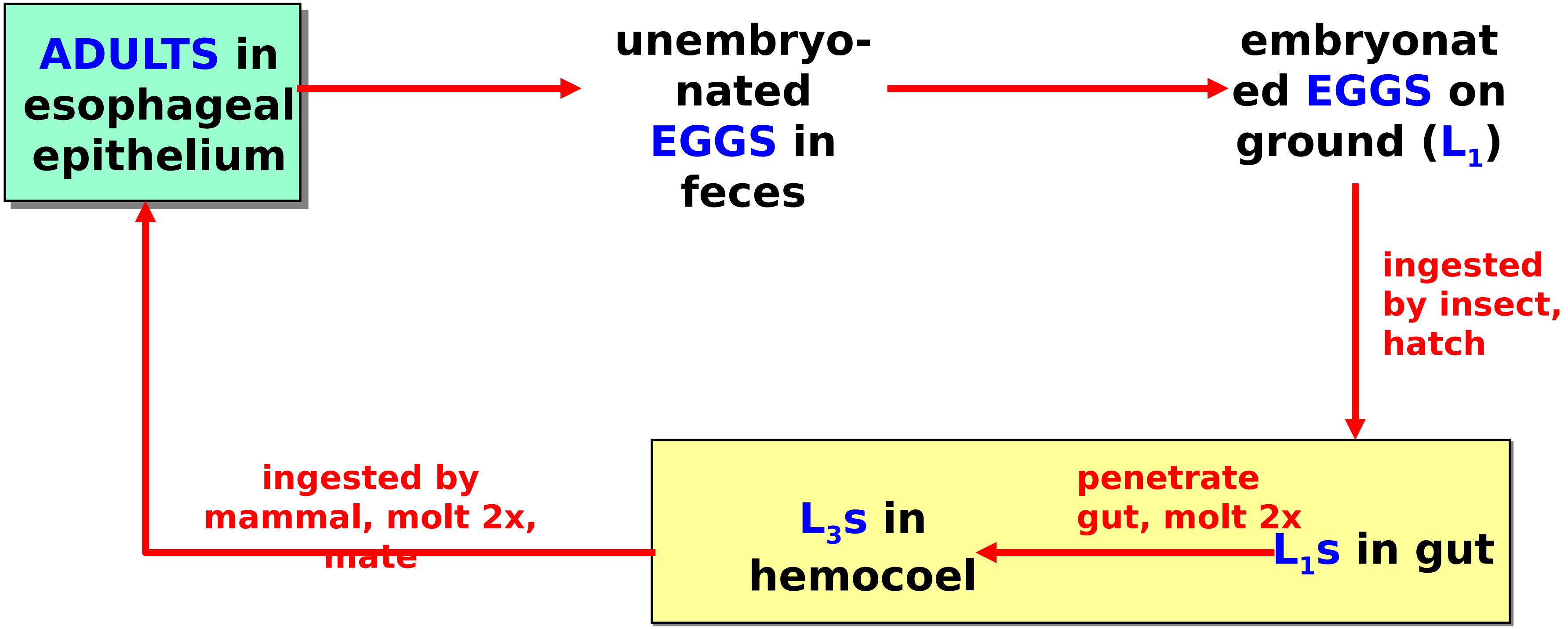
L_3s in mouth parts

invade bite wound, molt 2x, mate

🟩 definitive host

🟨 intermediate host

Life cycle of *Gongylonema ingluvicola*



ADULTS in esophageal epithelium

unembryonated EGGS in feces

embryonated EGGS on ground (L_1)

ingested by insect, hatch

L_1s in gut

penetrate gut, molt 2x

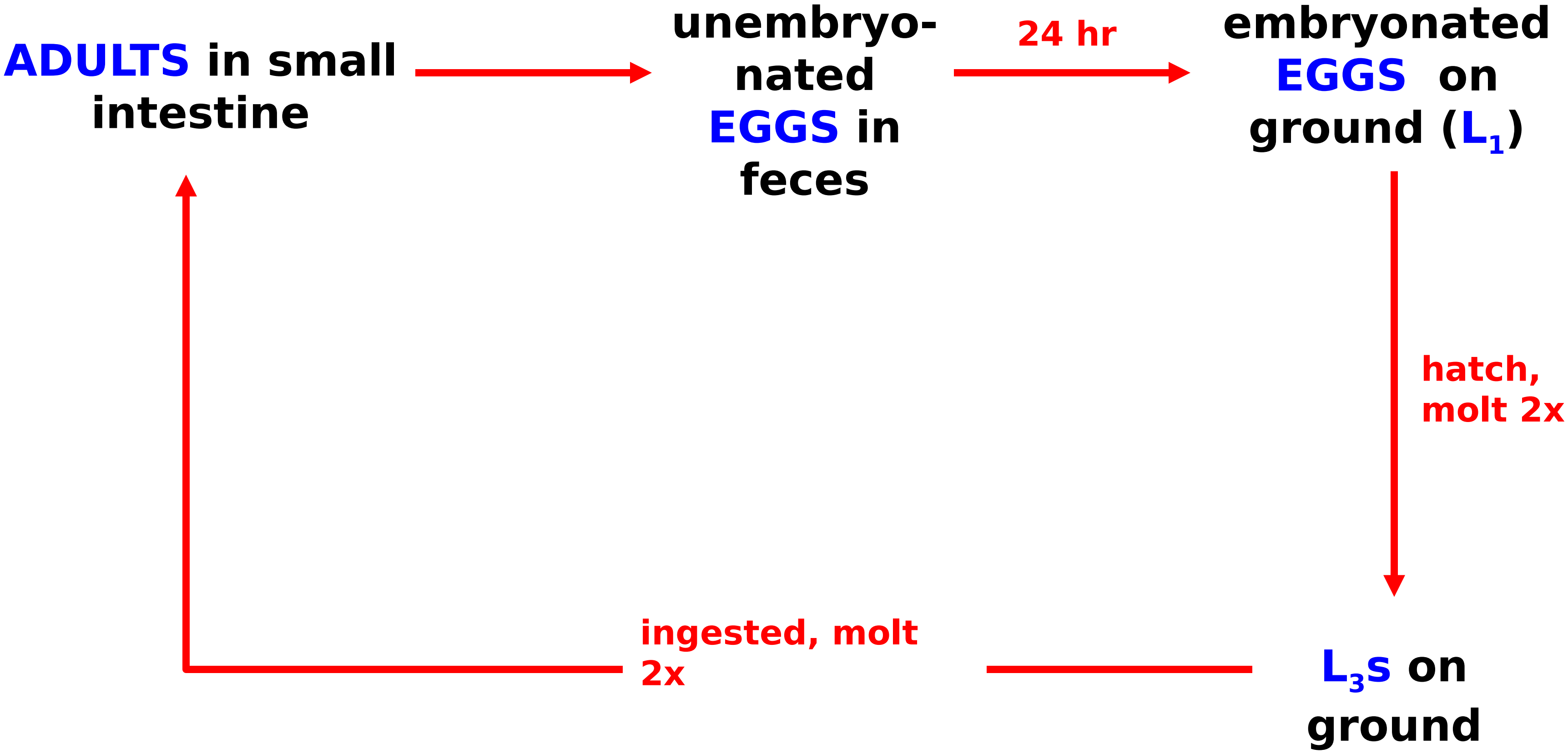
L_3s in hemocoel

ingested by mammal, molt 2x, mate

🟩 **definitive host**

🟨 **intermediate host**

Life cycle of *Trichostrongylus* spp.



ADULTS in small intestine

unembryonated **EGGS** in feces

24 hr

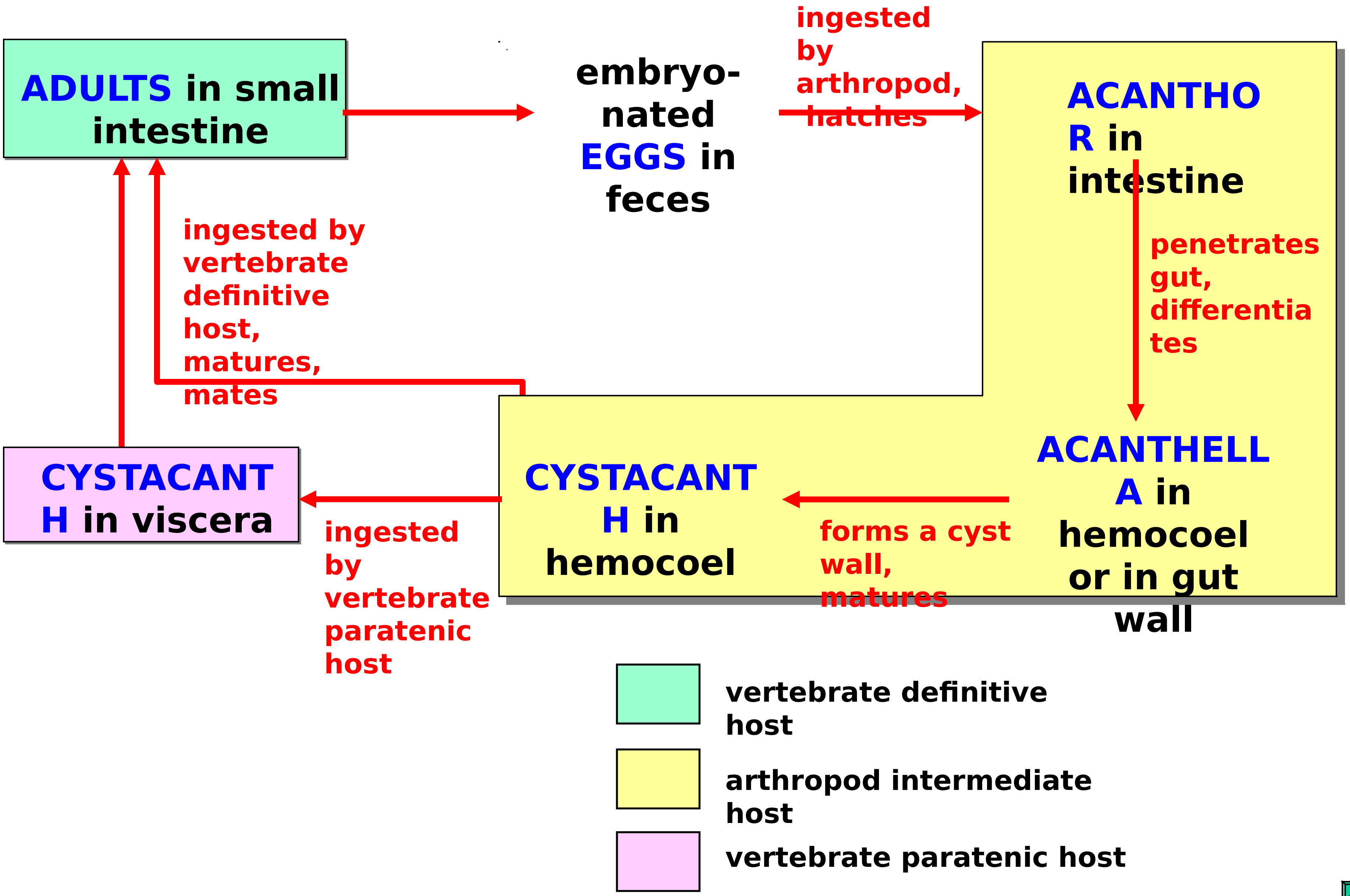
embryonated **EGGS** on ground (L_1)

hatch, molt 2x

L_3s on ground

ingested, molt 2x

Life cycle of Acanthocephala



ADULTS in small intestine

embryonated **EGGS** in feces

ingested by arthropod, hatches

ACANTHOR in intestine

penetrates gut, differentiates

ACANTHELLA in hemocoel or in gut wall

forms a cyst wall, matures

CYSTACANTH in hemocoel

ingested by vertebrate paratenic host

CYSTACANTH in viscera

ingested by vertebrate definitive host, matures, mates

🟩 vertebrate definitive host

🟨 arthropod intermediate host

🟪 vertebrate paratenic host

Self Test - Protozoa

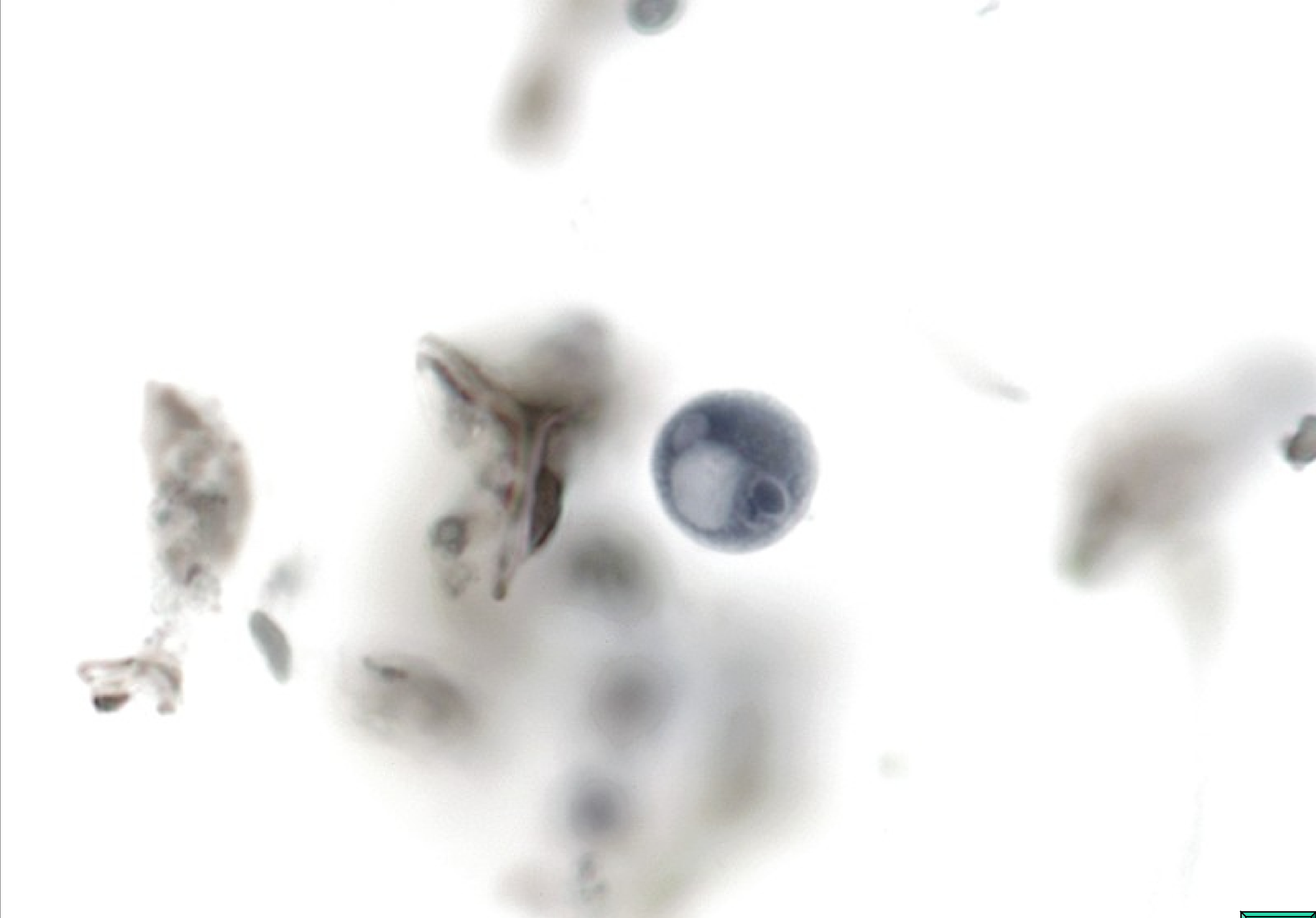
Start | Start | Start | Start

For each specimen, name the genus, species, and developmental stage. Hypothetical source of the specimen is usually given.

- ? provides the answer along with diagnostic features.
- ↺ returns you to the photograph of the specimen.
- ⏮ returns you to this slide.

By choosing a different Start button, and then proceeding forward or backward, you can vary the sequence of questions each time you take the test.

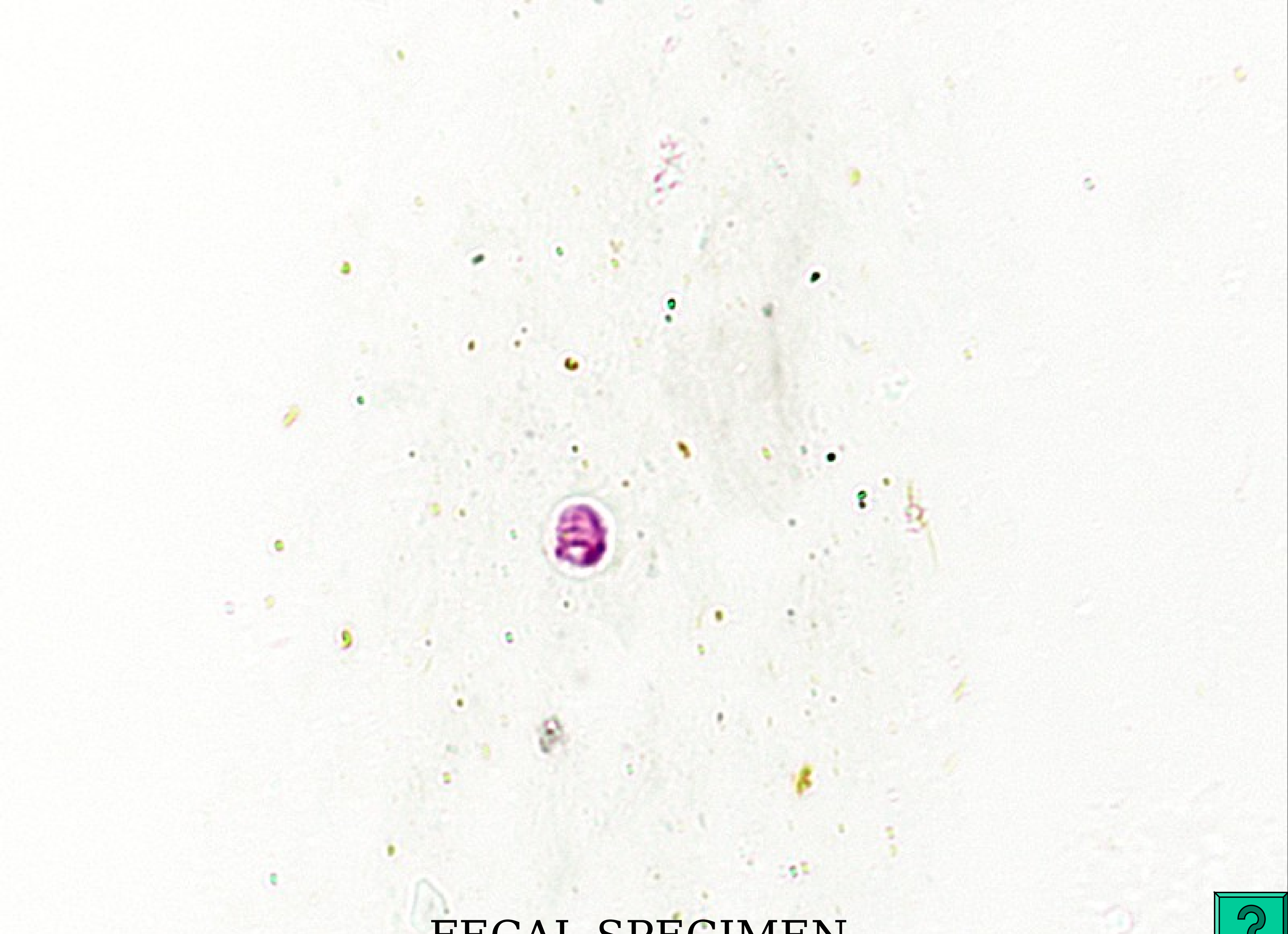
I T



FECAL SPECIMEN

Iodamoeba butschlii cyst

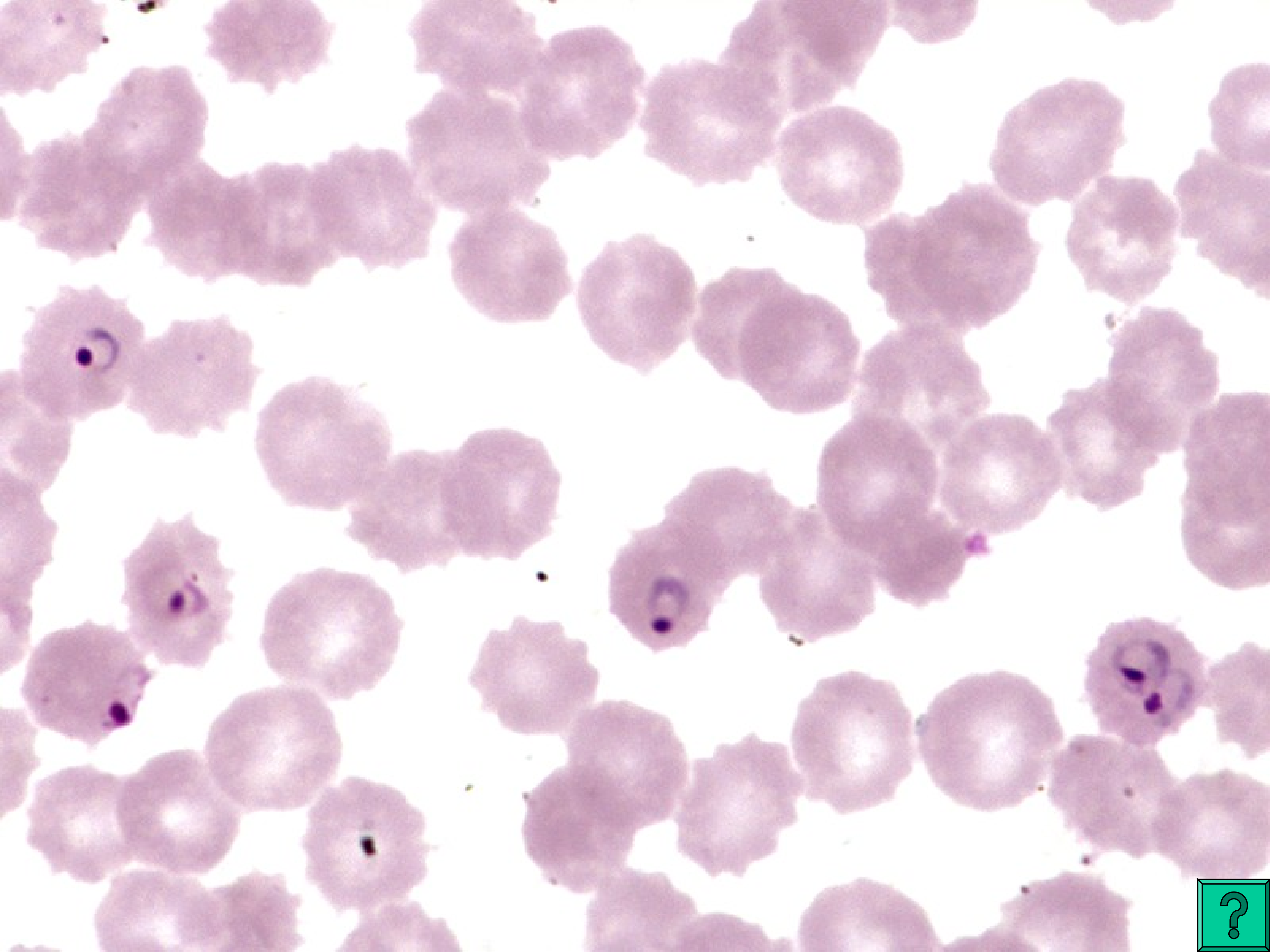
- oblong or spherical
- single nucleus
- large nuclear endosome
- large cytoplasmic vacuole



FECAL SPECIMEN

Cryptosporidium parvum oocyst

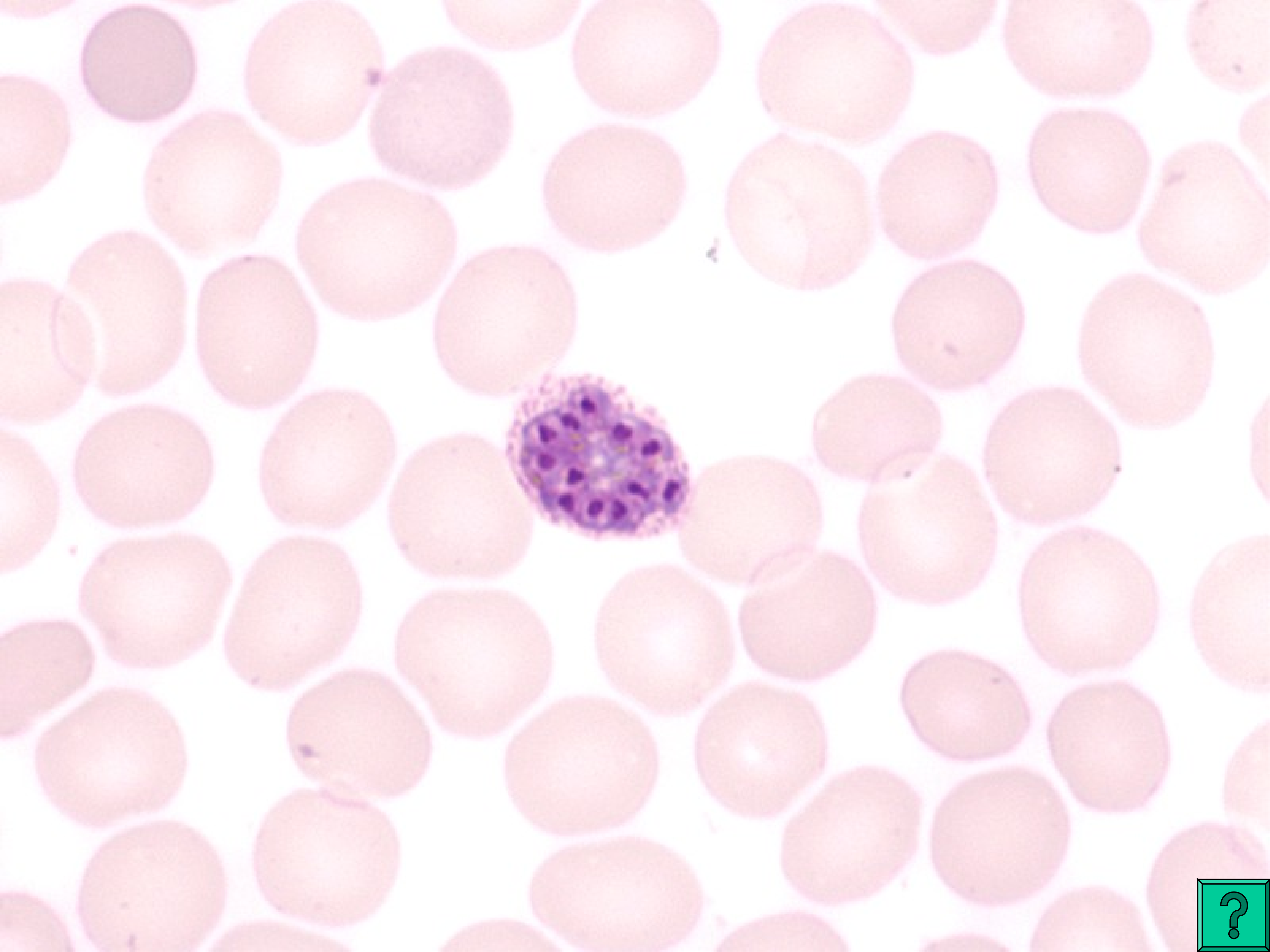
- small
- spherical
- clear cyst wall
- 4 sporozoites



?

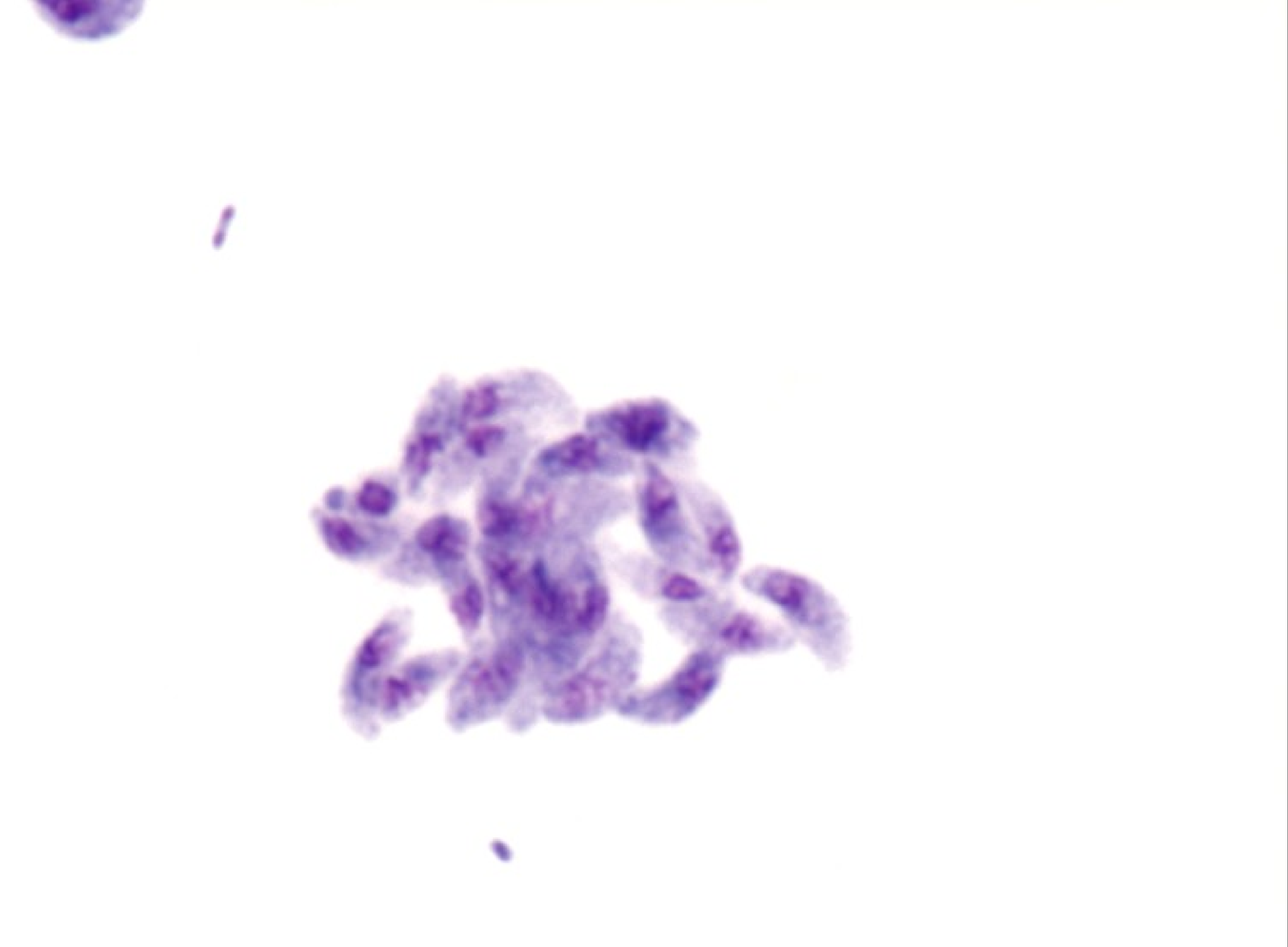
Plasmodium falciparum young trophozoites

- high parasitemia
- only small signet ring stages present
- double infection
- appliqué form
- no Schüffner’s dots
- infected RBCs not enlarged or decolorized



Erythrocytic schizont of *Plasmodium ovale*

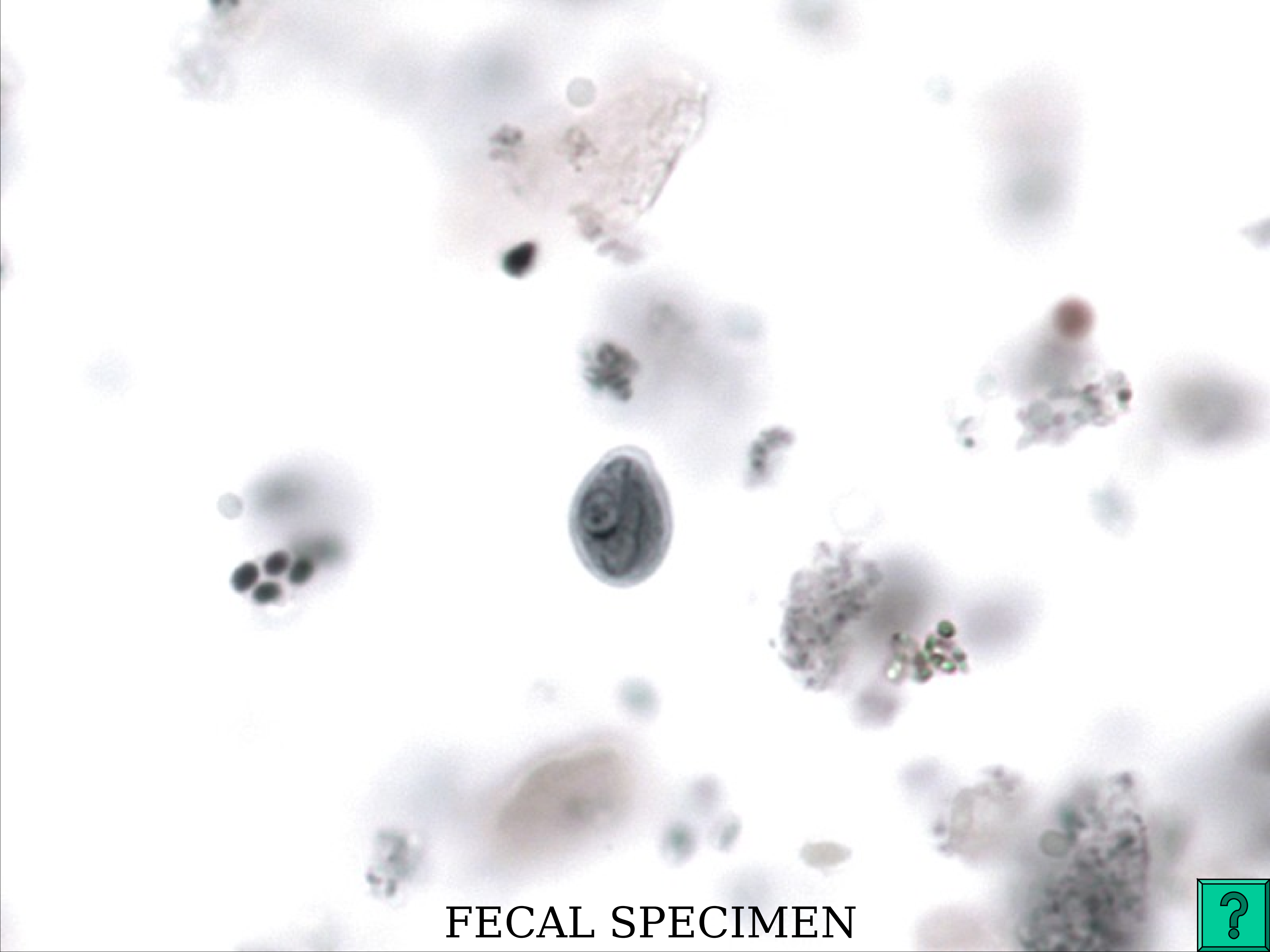
- enlarged, ovally-distorted RBC
- prominent Schüffner’s dots
- low number of developing merozoites



SMEAR OF PERITONEAL

Toxoplasma gondii tachyzoites

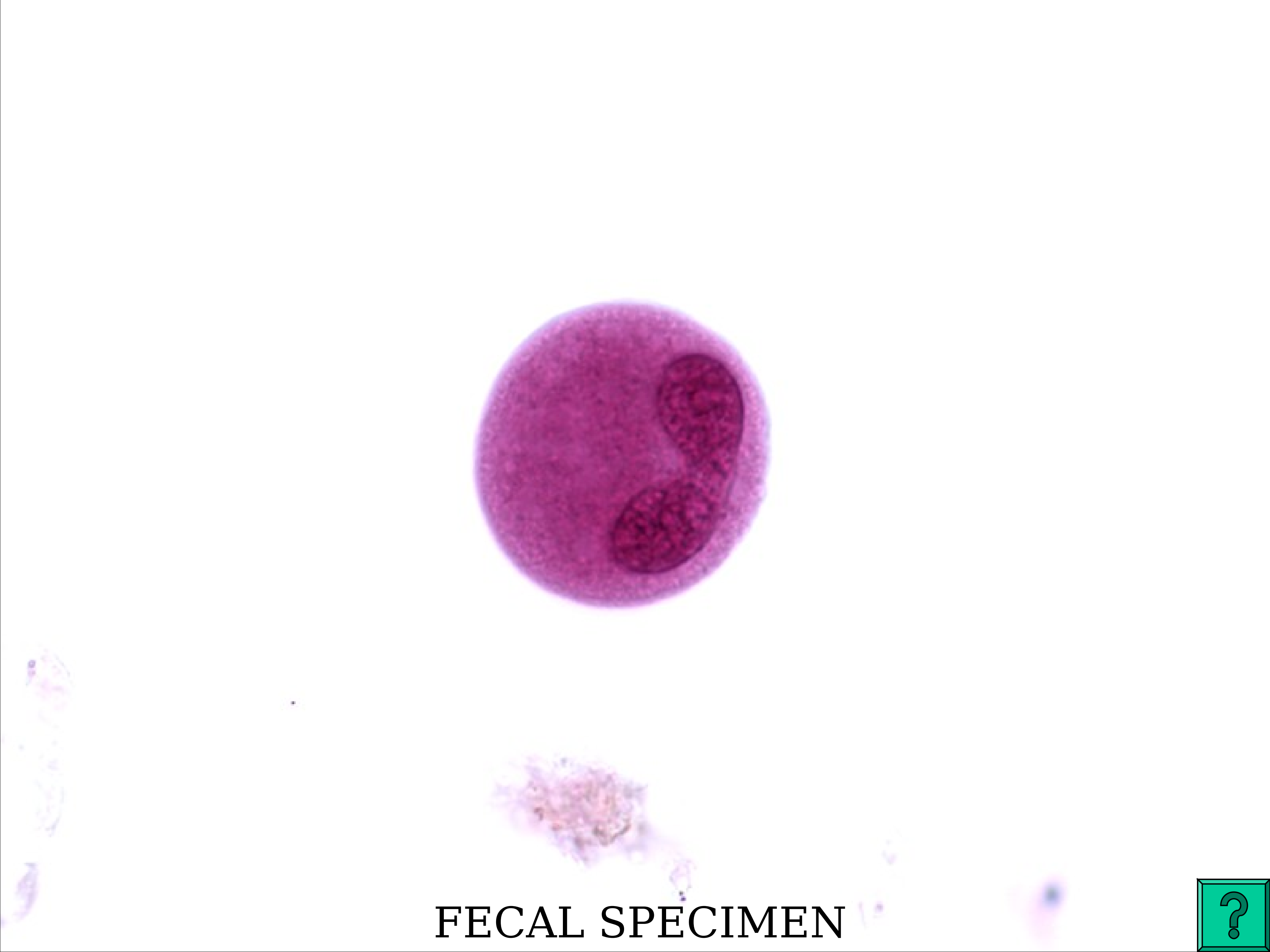
- banana (crescent)-shaped
- central nucleus
- no kinetoplast



FECAL SPECIMEN

Chilomastix mesnili cyst

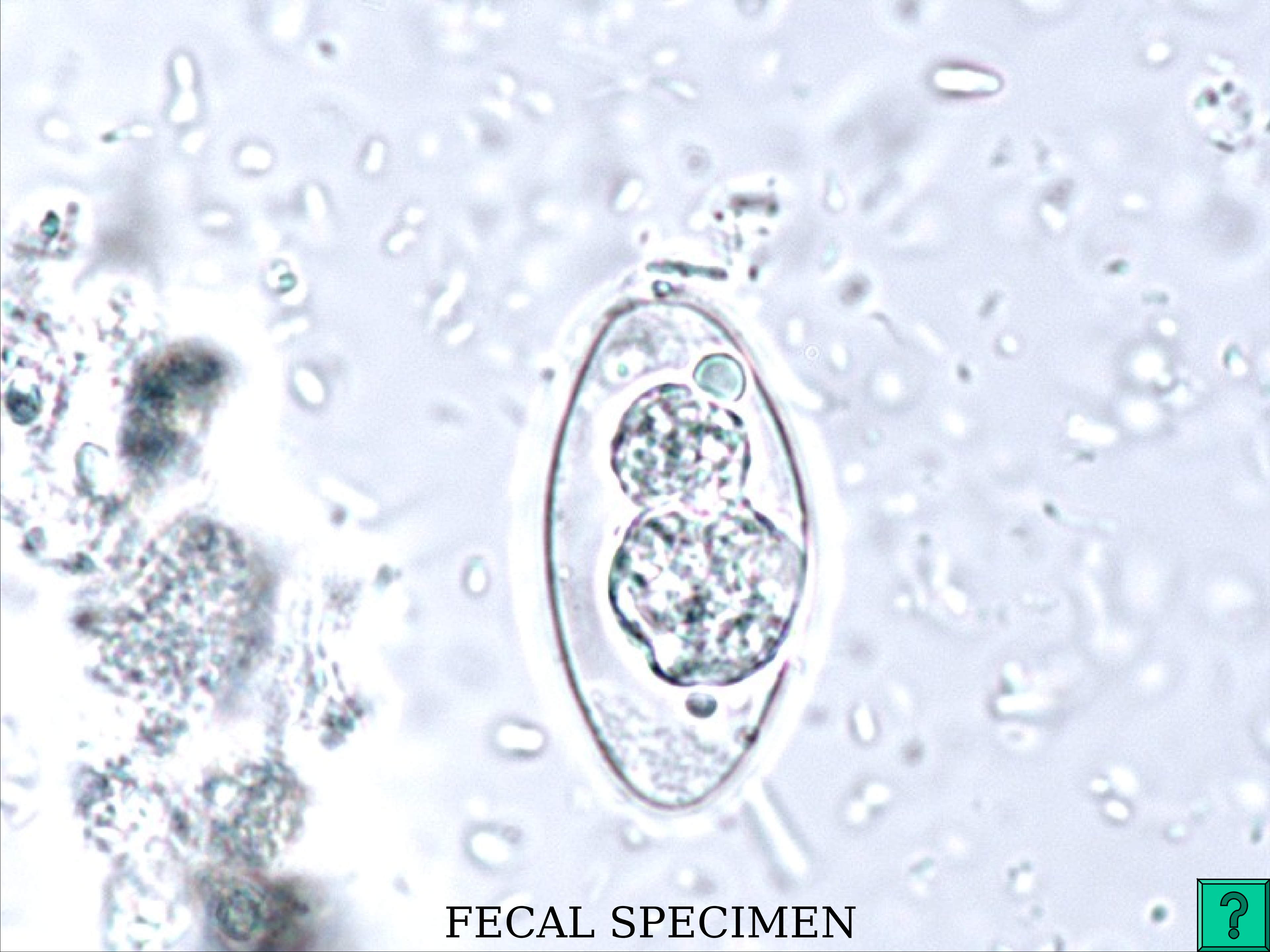
- lemon-shaped
- “cap” at narrow end
- single nucleus
- no nuclear endosome
- cytostomal groove present



FECAL SPECIMEN

Balantidium coli cyst

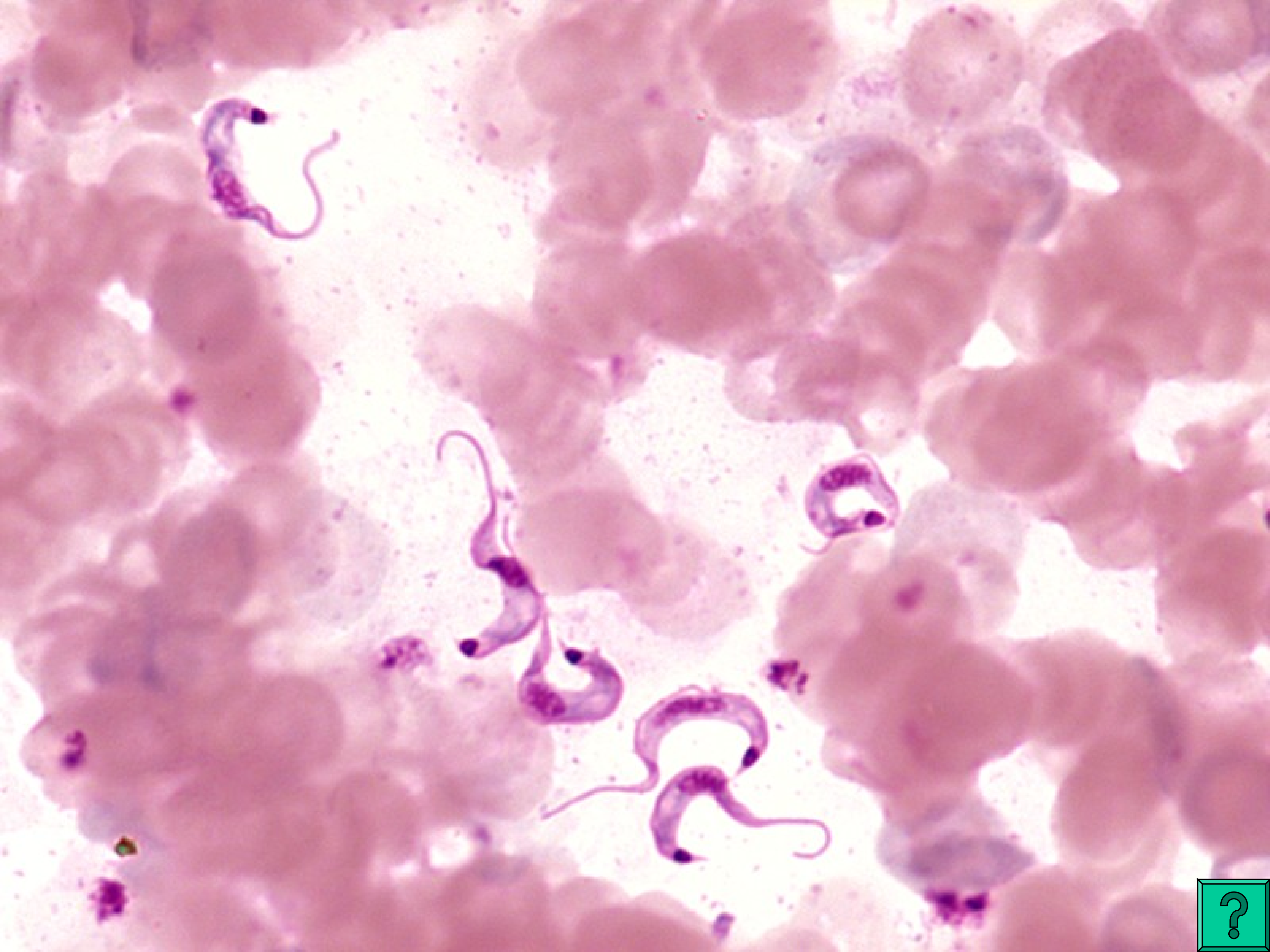
- large
- round
- macronucleus



FECAL SPECIMEN

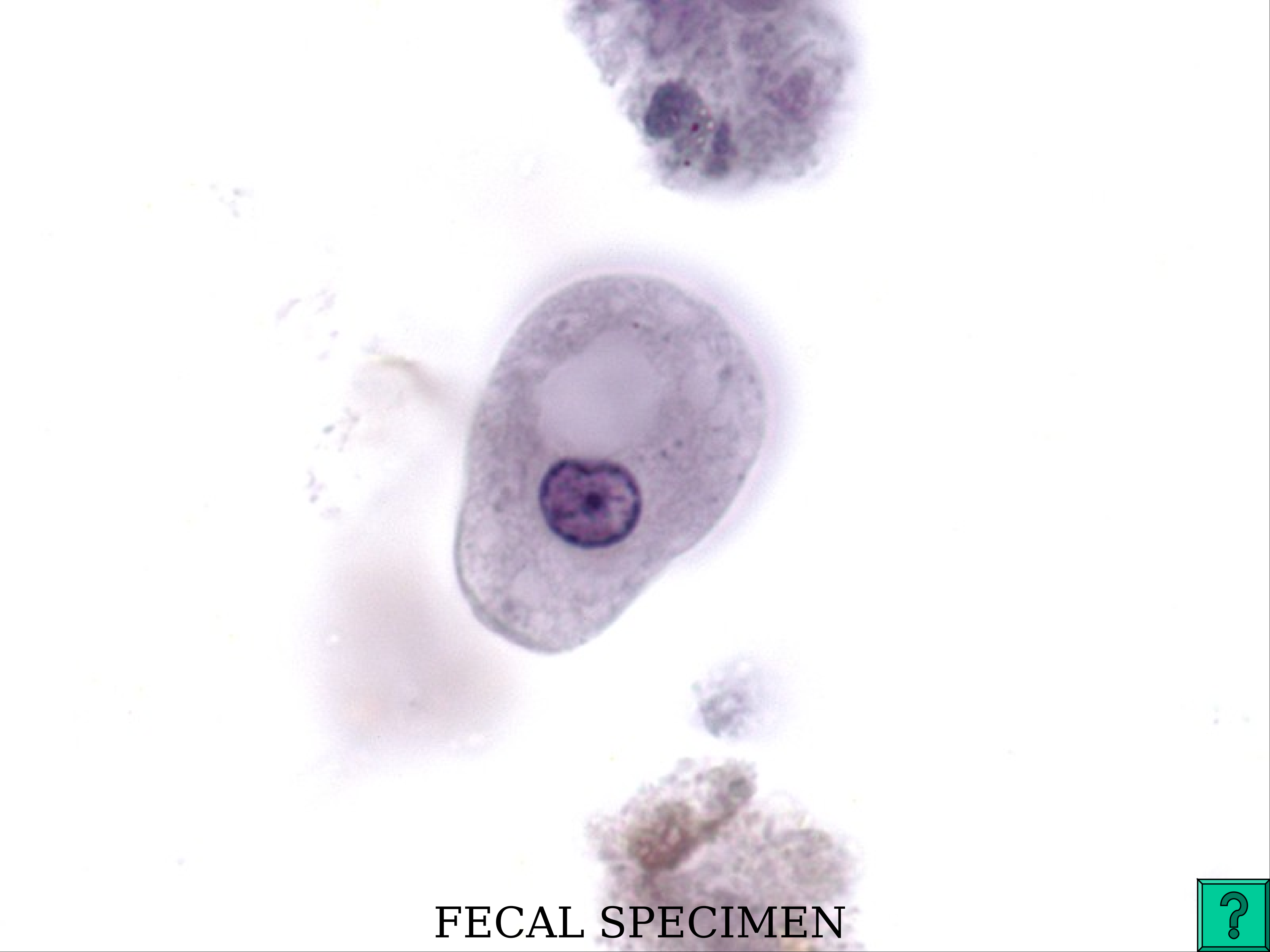
Isospora belli immature oocyst

- ovoid
- thin cyst wall
- one or two sporoblasts
- polar granule



Trypanosoma cruzi trypomastigotes

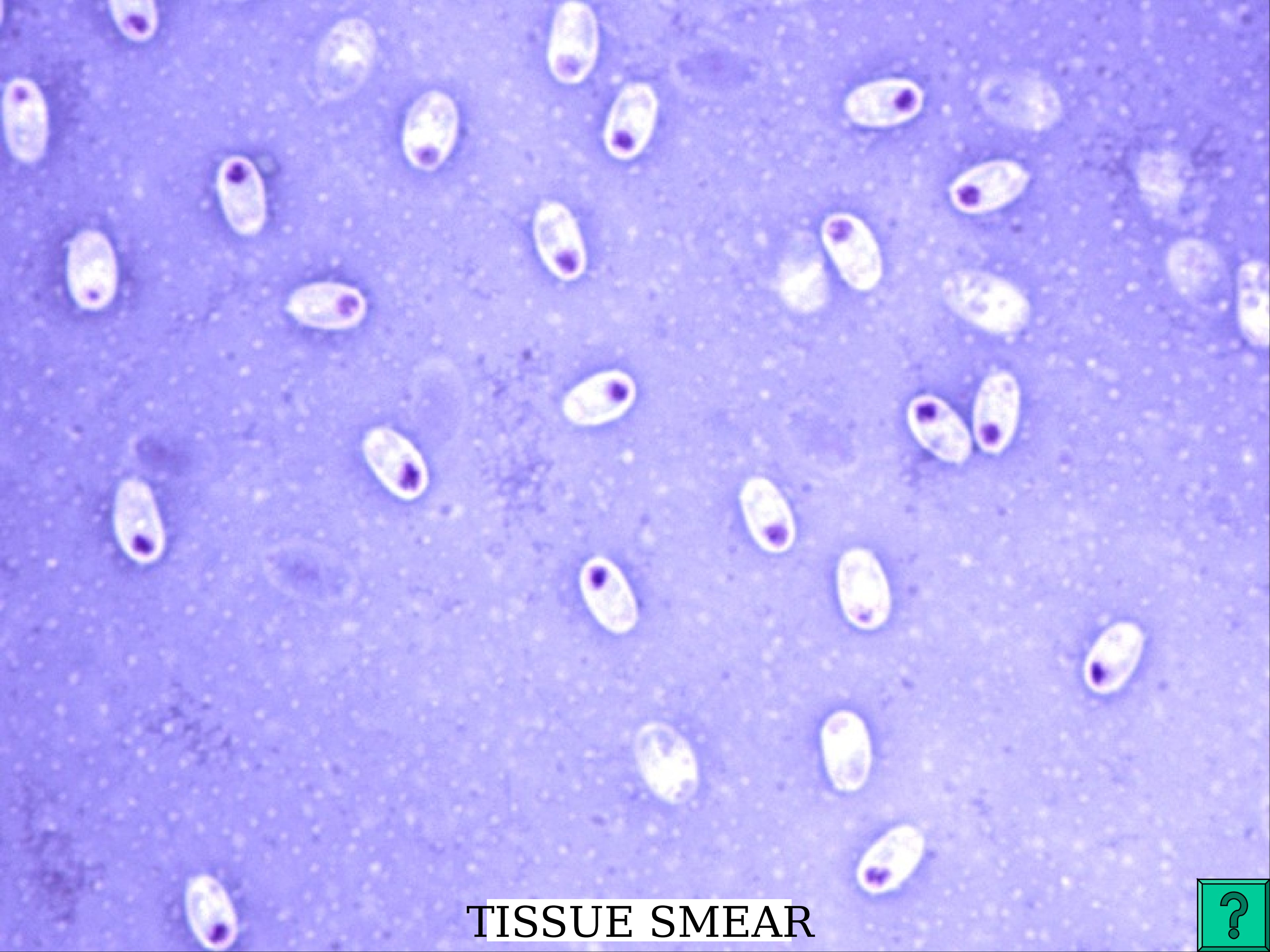
- undulating membrane
- free flagellum
- prominent kinetoplast
- often “C” or “?” shaped when fixed
- relatively low parasitemia
- nondividing
- no volutin granules in cytoplasm



FECAL SPECIMEN

Entamoeba histolytica trophozoite

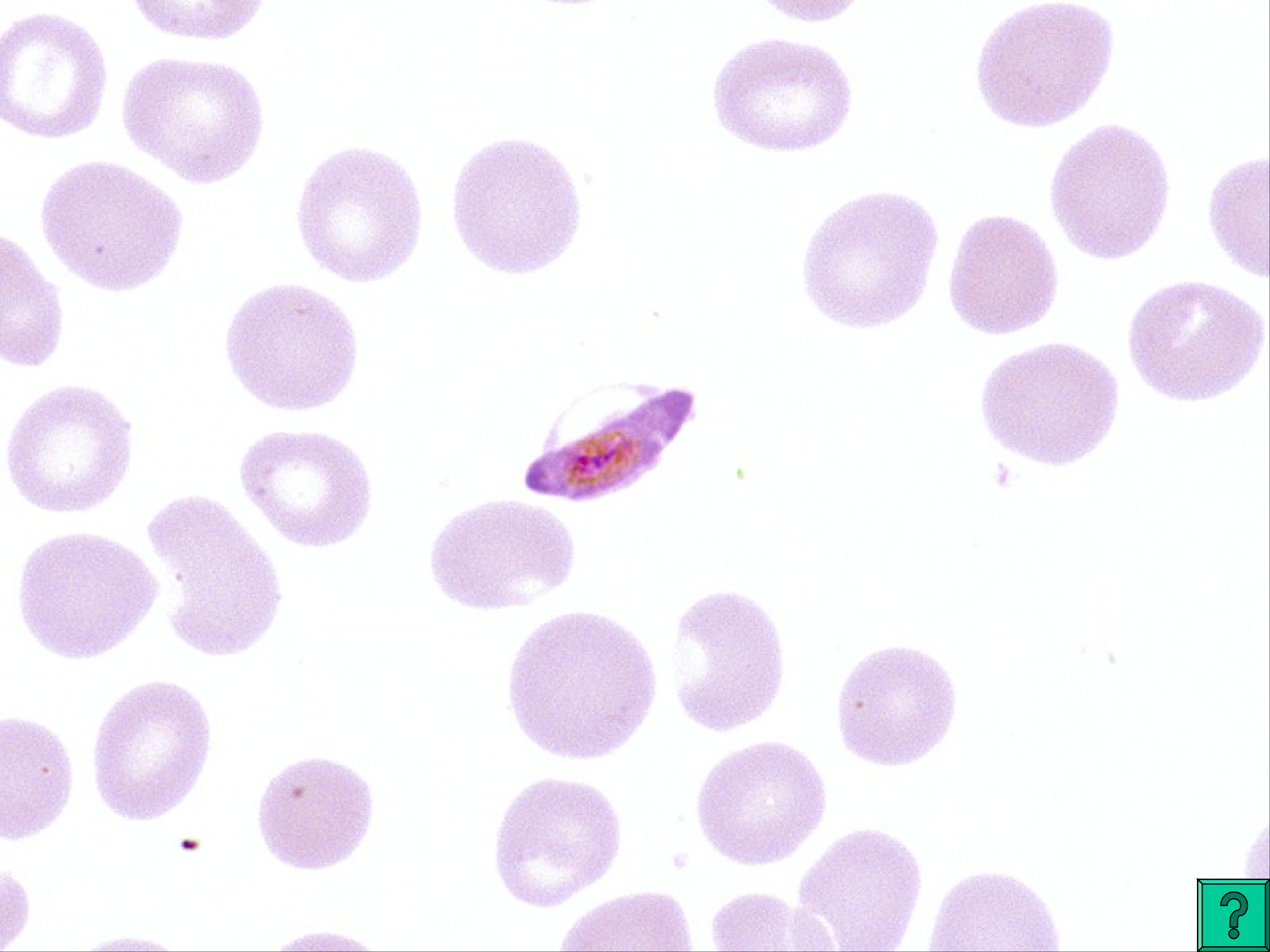
- irregular shape
- central, small, discrete nuclear endosome
- fine, evenly distributed peripheral ring of chromatin
- relatively clean, finely granular cytoplasm



TISSUE SMEAR

Microsporidian spores

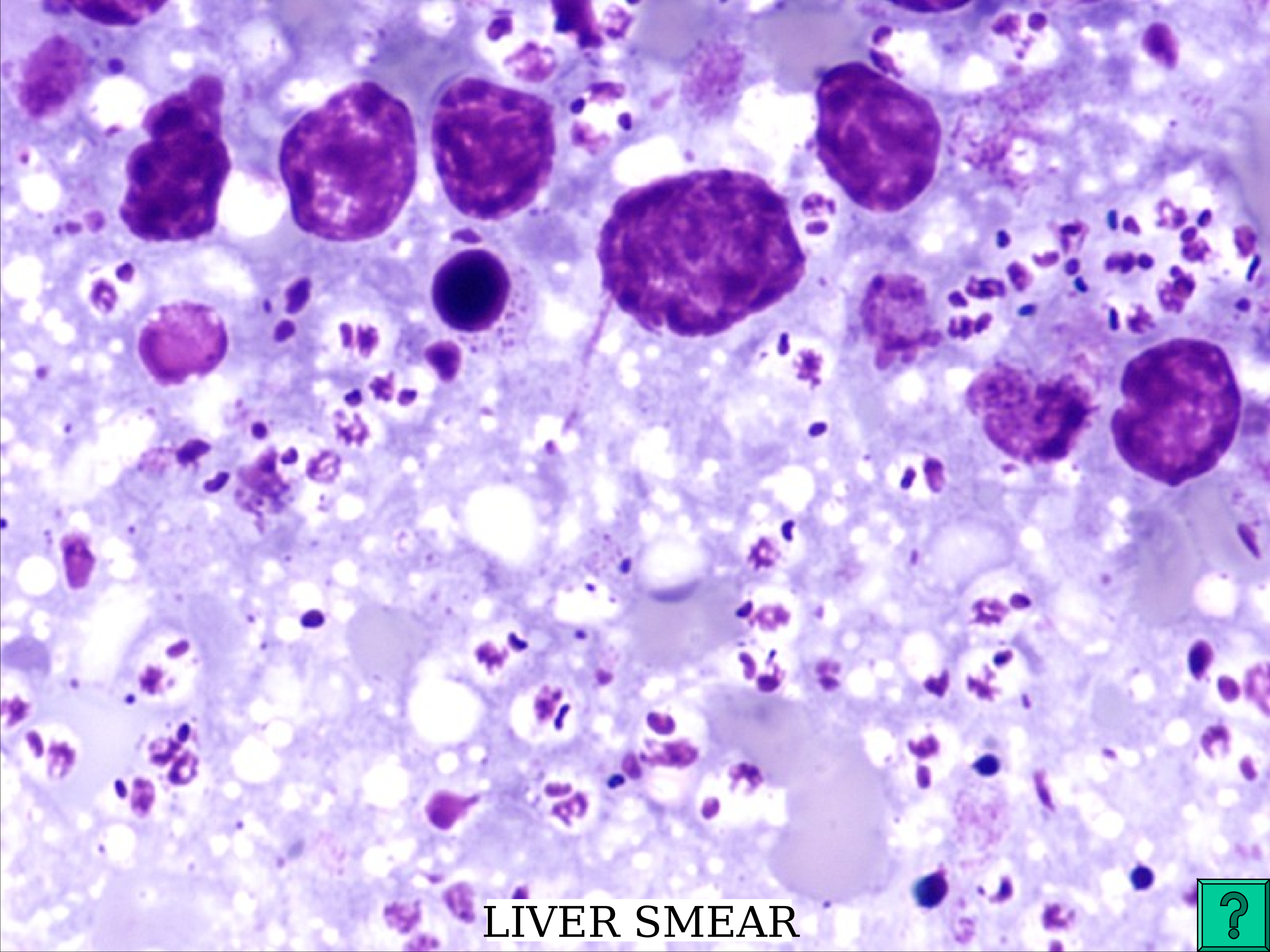
- ovoid, unicellular spore
- dense, refractile spore wall
- posterior vacuole
- spores single or in groups



?

Plasmodium falciparum microgametocyte

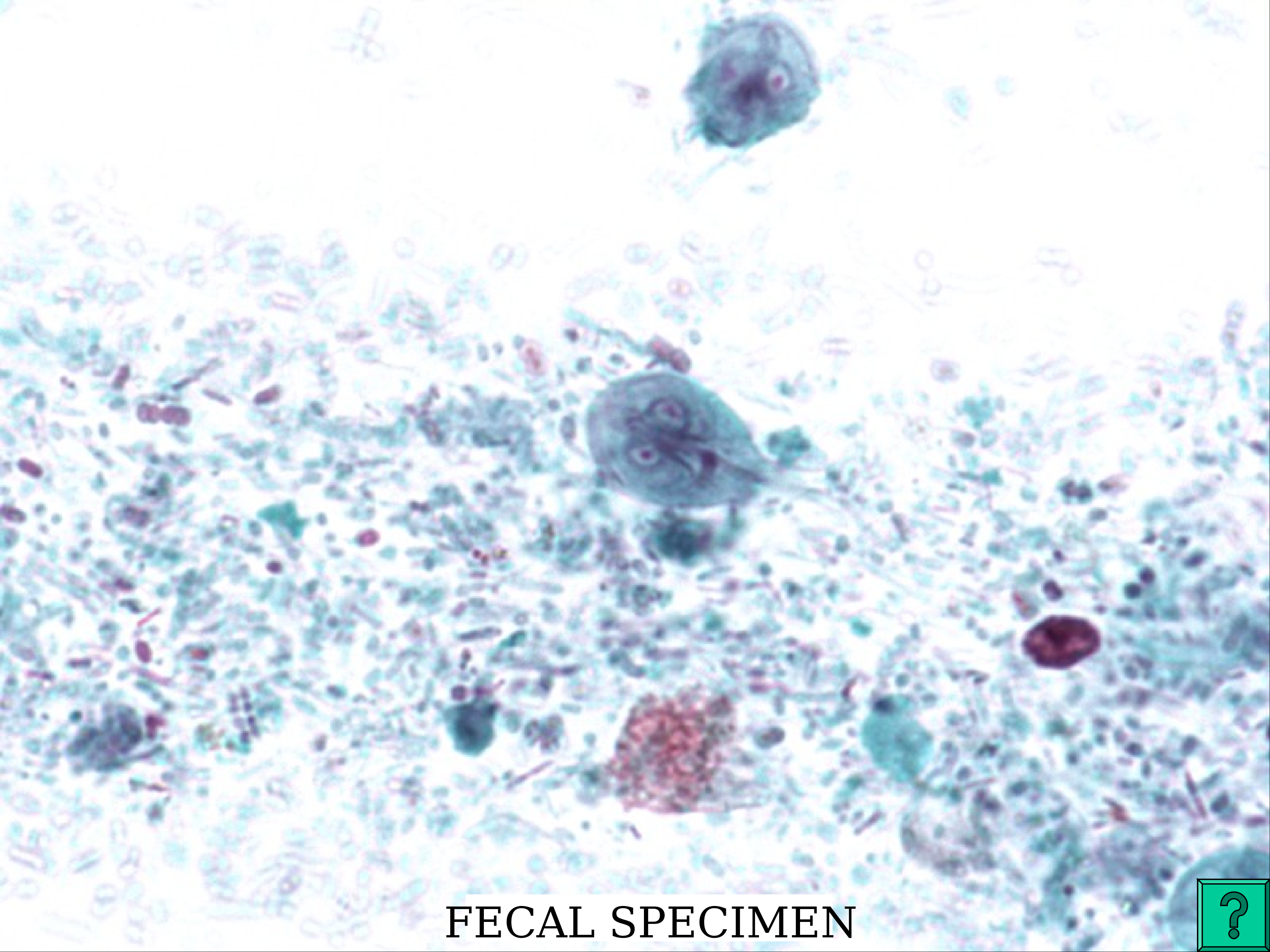
- presence of hemozoin granules around nucleus
- short, with blunt ends
- nucleus > one-half cell length



LIVER SMEAR

Trypanosoma cruzi (or *Leishmania donovani*) amastigotes

- intracellular parasite
- small, ovoid cell
- uninucleate
- darkly stained kinetoplast

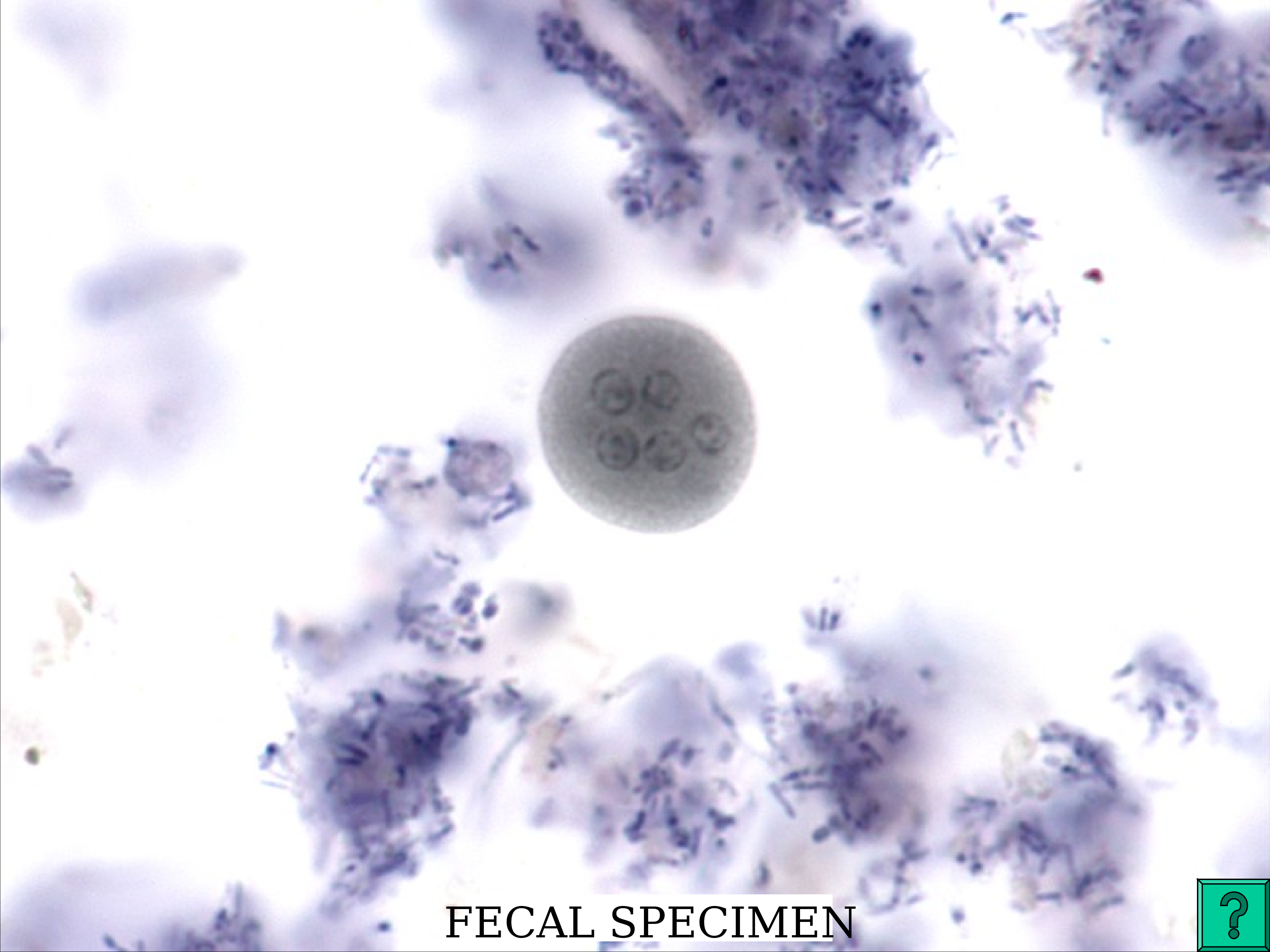


FECAL SPECIMEN

?

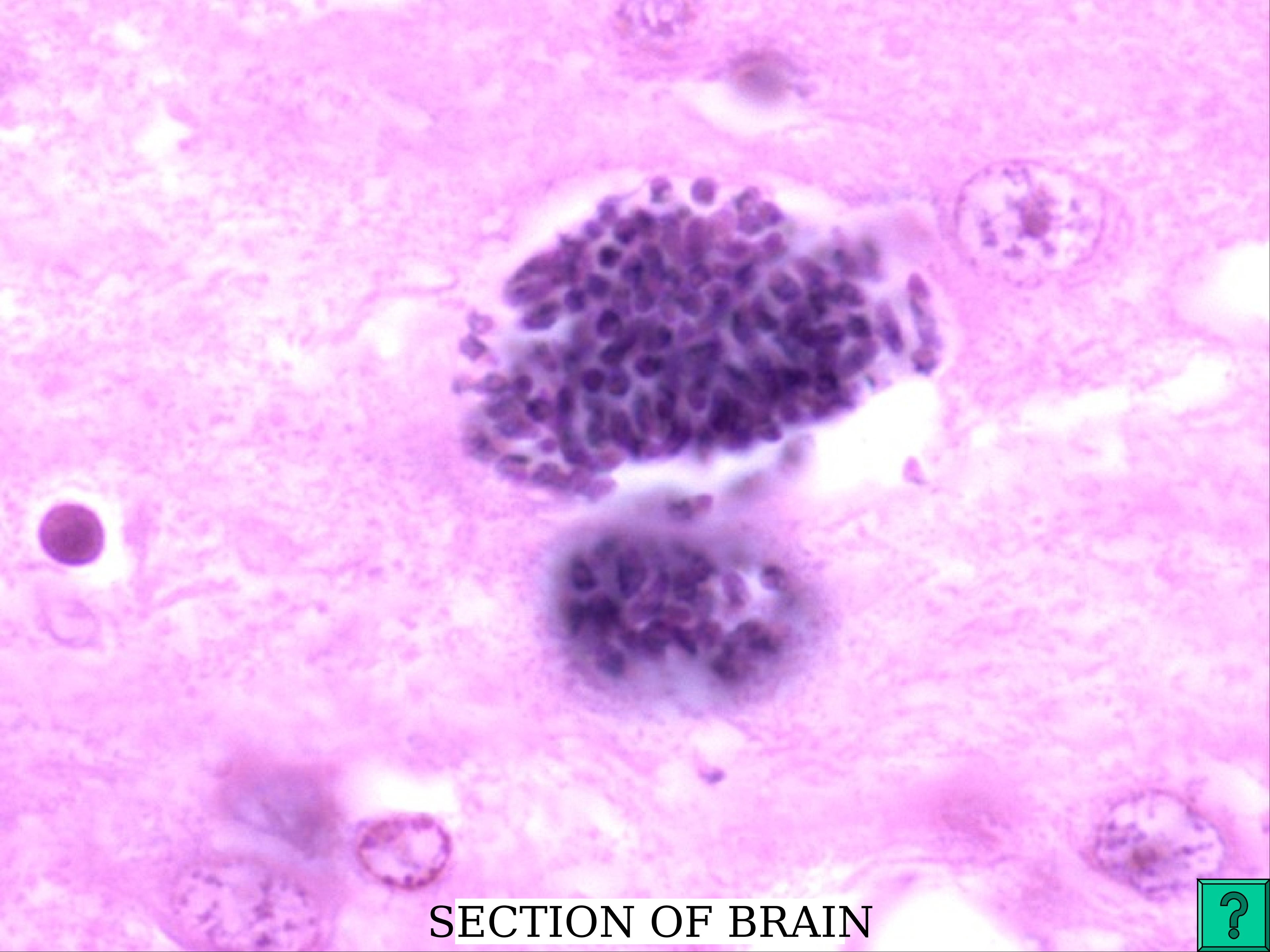
Giardia lamblia trophozoite

- rounded anterior end, pointed posteriorly
- dorsoventrally flattened
- two nuclei, with endosomes
- adhesive disk
- intracytoplasmic axonemes
- median bodies


FECAL SPECIMEN

Entamoeba coli cyst

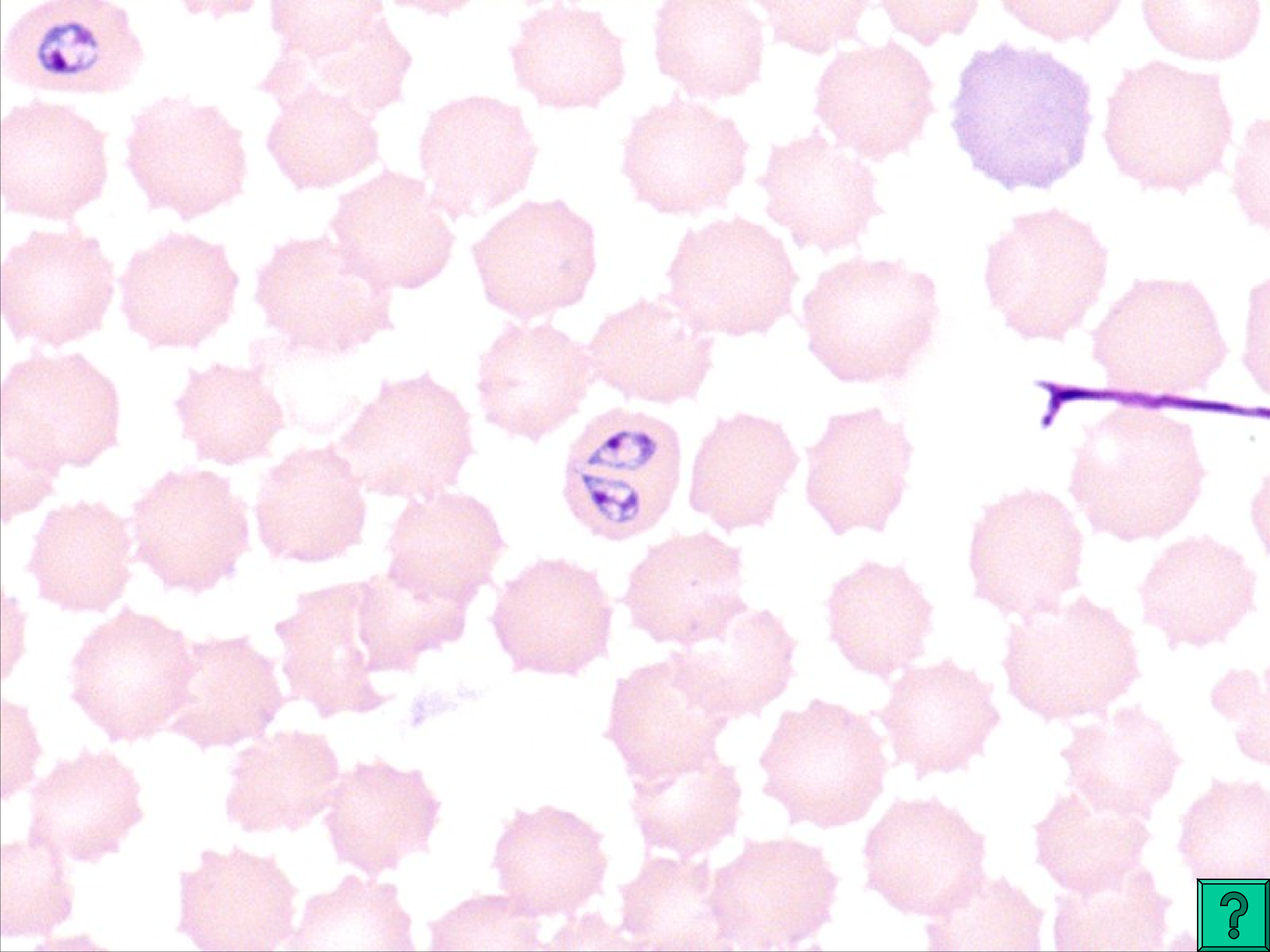
- spherical
- 8 nuclei (5 are visible), with eccentric endosomes
- coarse peripheral chromatin
- cytoplasm coarsely granular



SECTION OF BRAIN

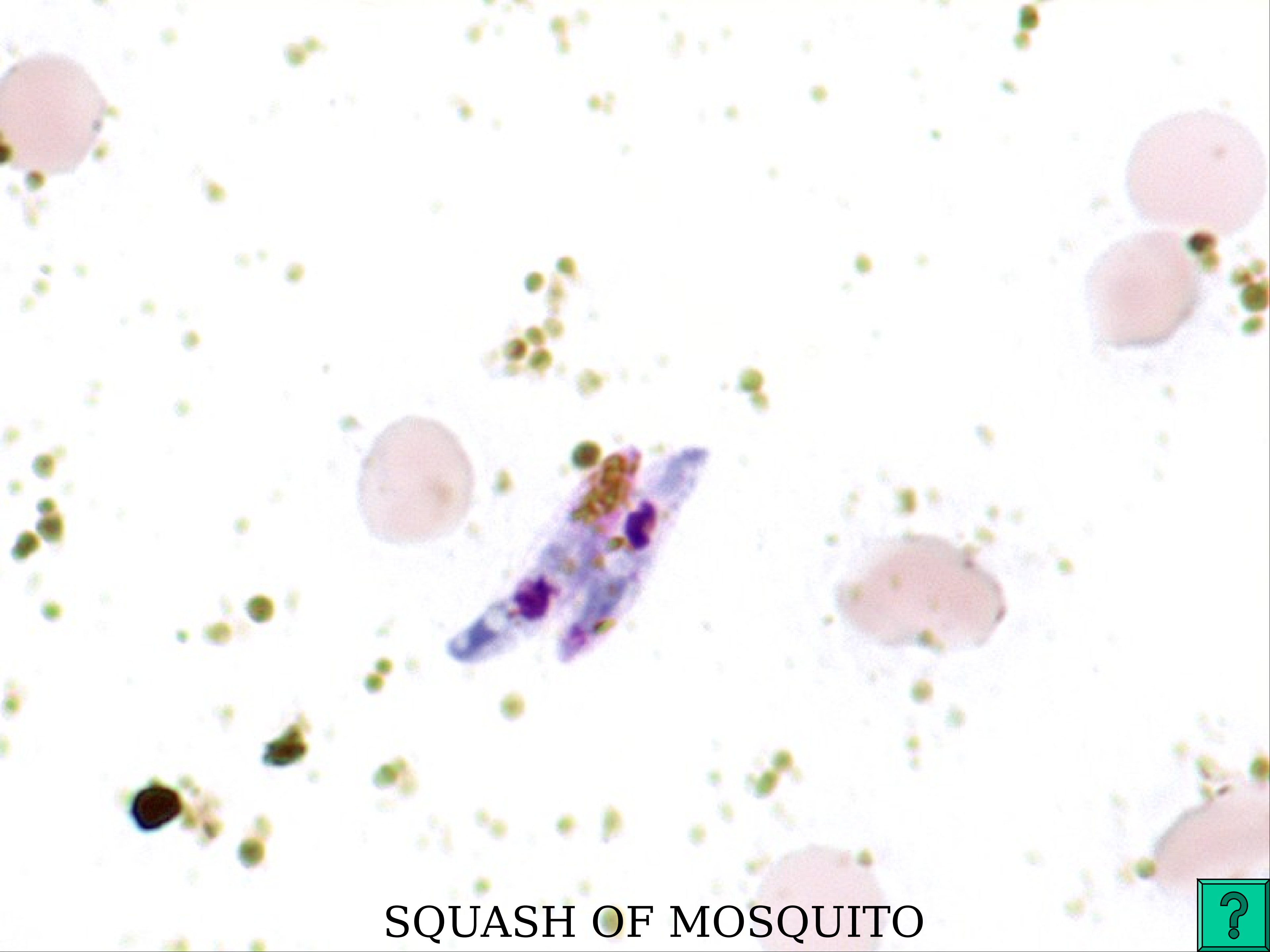
Toxoplasma gondii zoitocyst

- spherical
- intracellular
- contains numerous crescent-shaped bradyzoites
- absence of inflammation



Babesia bigemina trophozoites

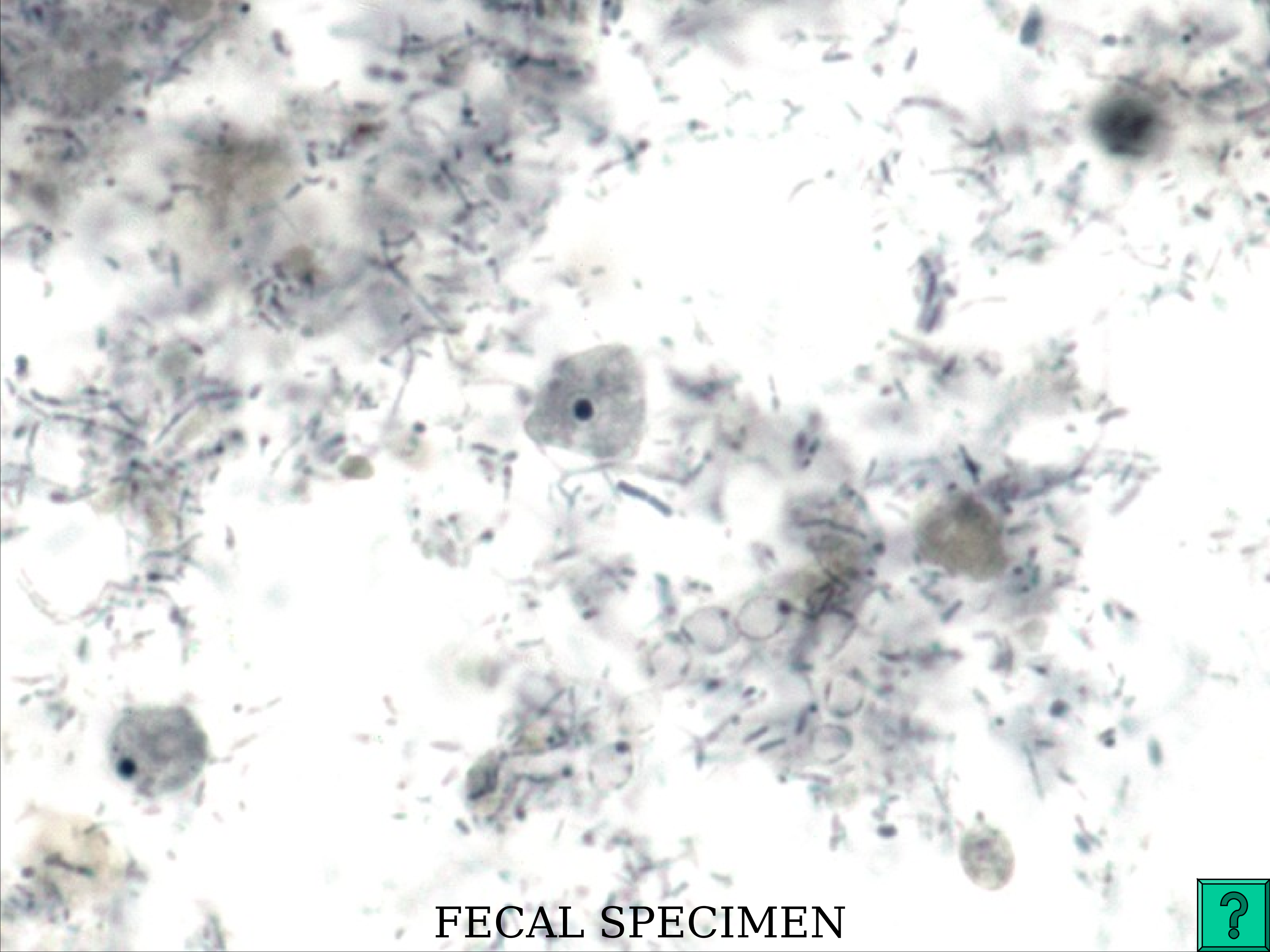
- tear drop-shape
- in pairs, joined at the tip
- no hemozoin granules or Schüffner’s dots



SQUASH OF MOSQUITO

Plasmodium sp. ookinetes

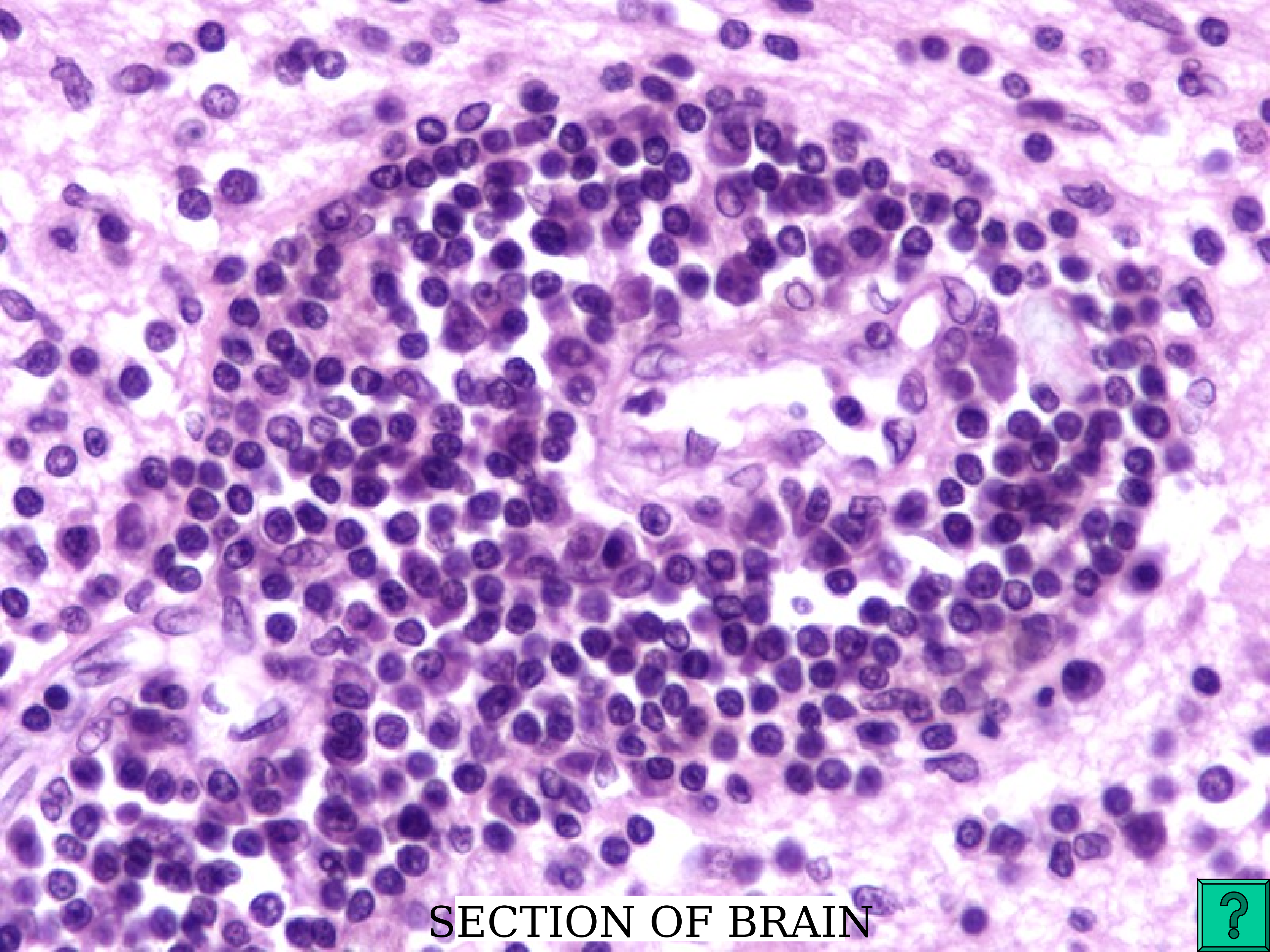
- elongate shape
- basophilic cytoplasm
- hemozoin granules



FECAL SPECIMEN

Endolimax nana trophozoite

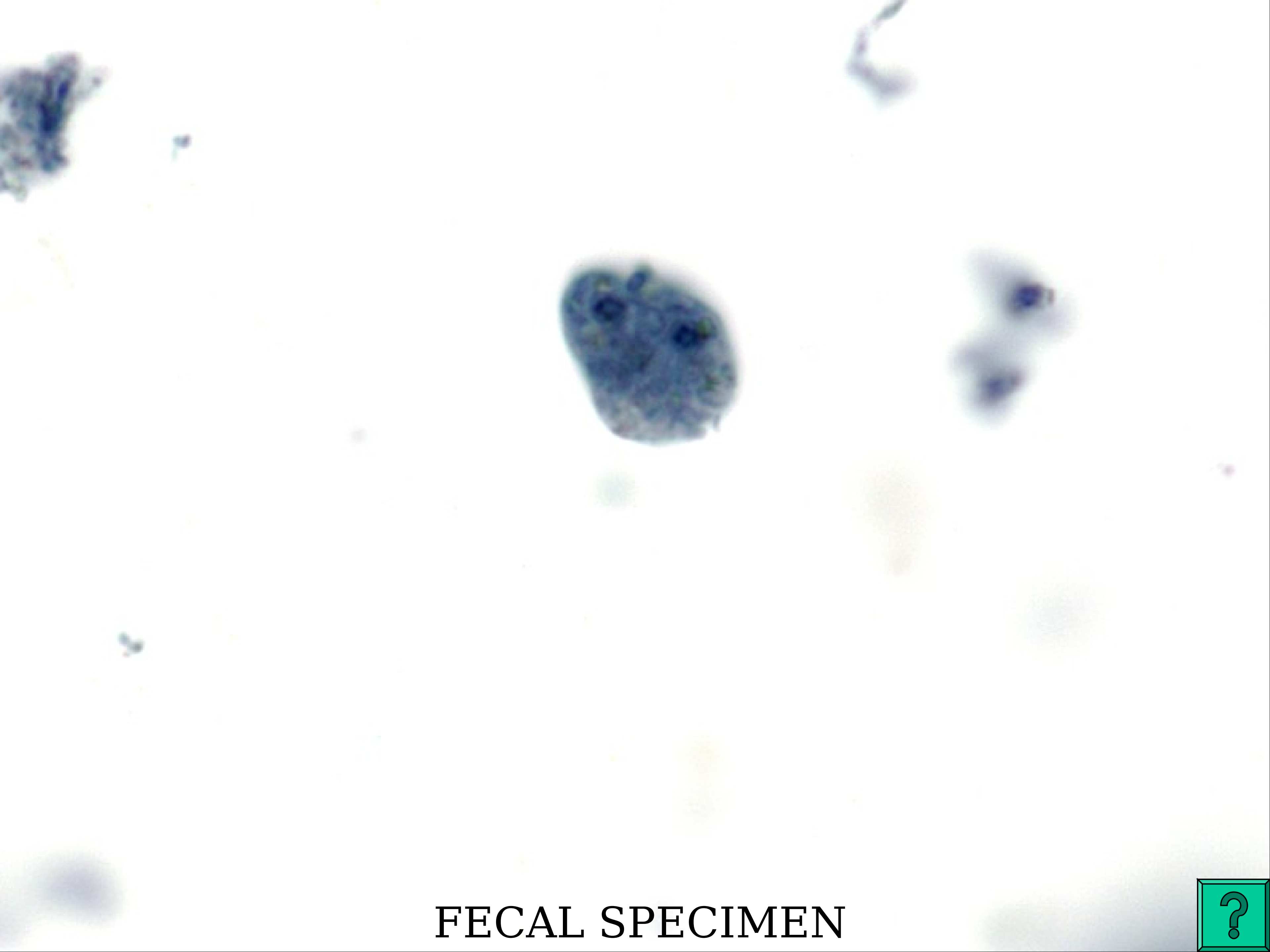
- small
- oval or irregular shape
- short, blunt pseudopodia
- large nuclear endosome
- no peripheral chromatin granules
- glycogen and food vacuoles in cytoplasm



SECTION OF BRAIN

Perivascular cuffing in African trypanosomiasis

- inflammatory cells surrounding blood vessel

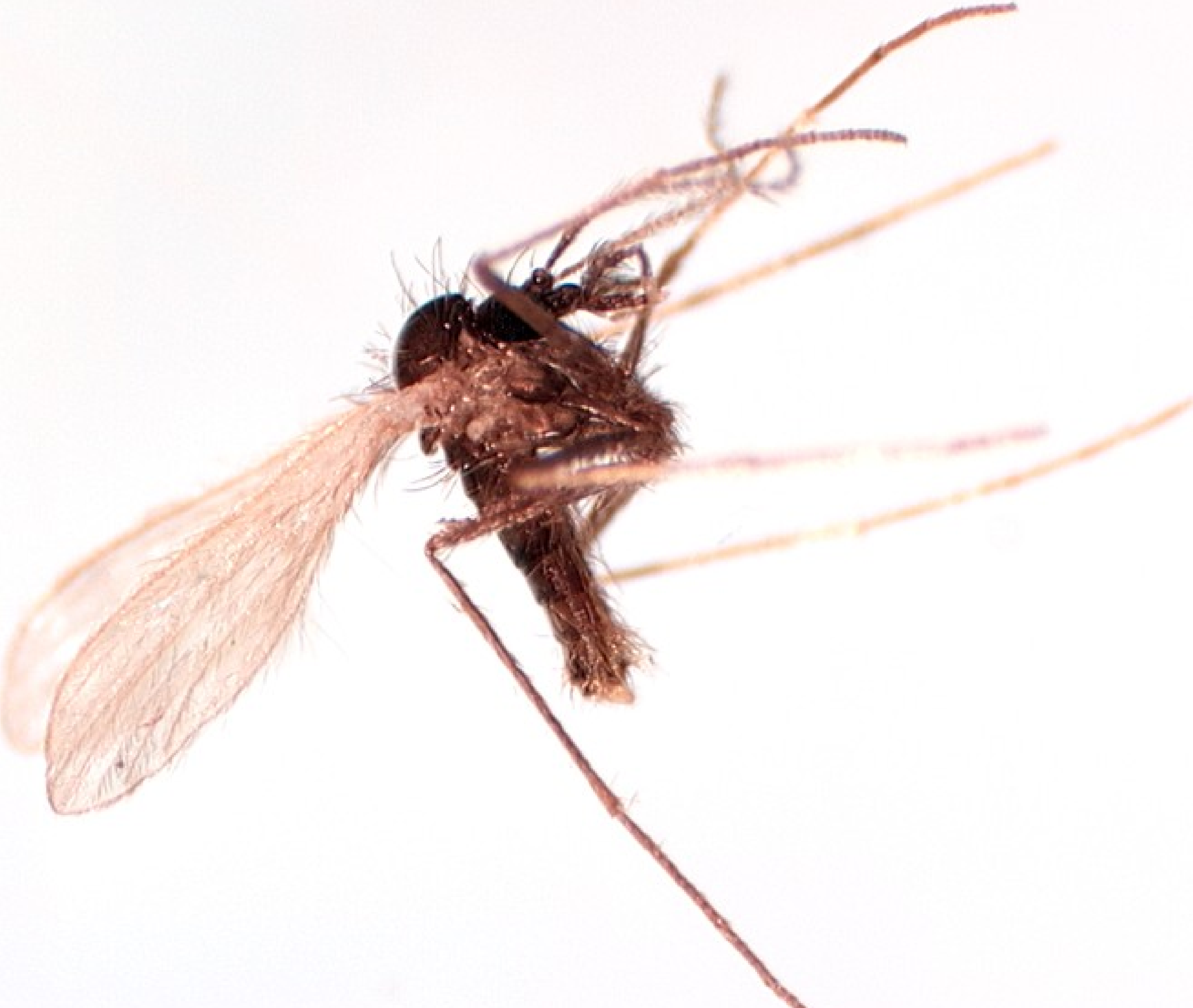


FECAL SPECIMEN

?

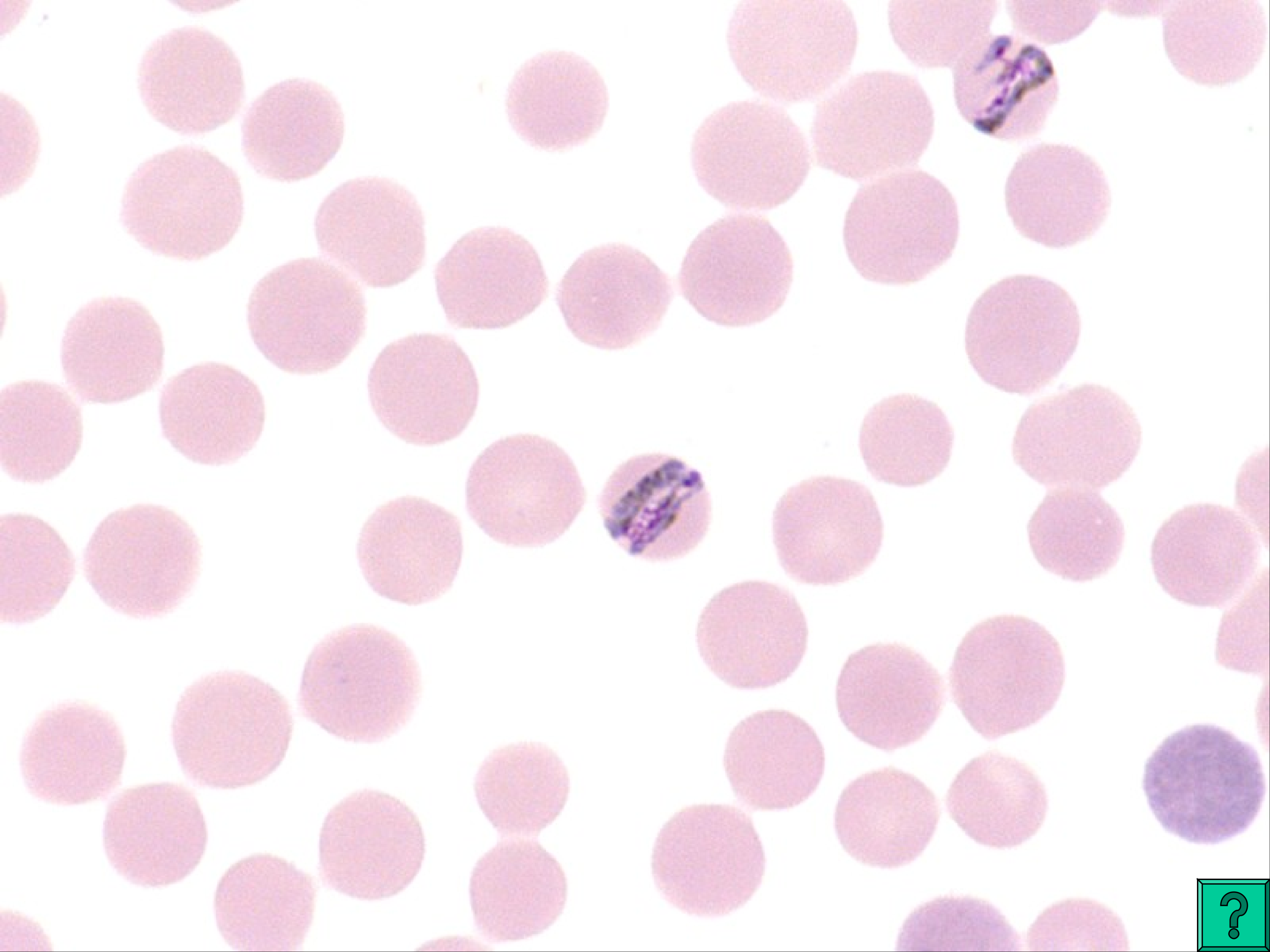
Dientamoeba fragilis trophozoite

- round to oval
- 2 nuclei
- fragmented nuclear endosome
- vacuolated cytoplasm



Sand fly (*Lutzomyia diabolica*)

- small size
- hairy wings and body
- wings held at 60 degrees from body at rest
- cutting mouthparts



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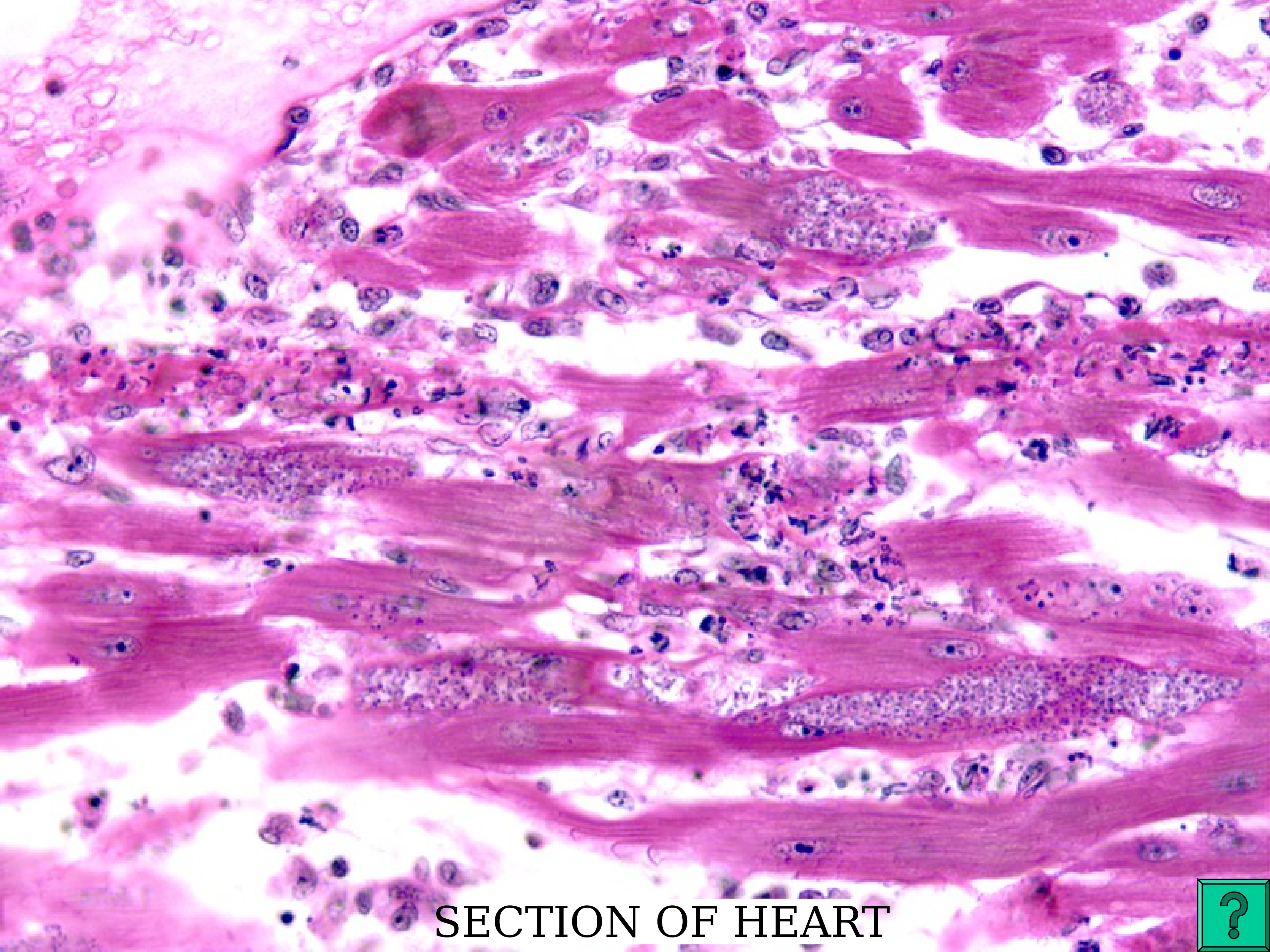
Plasmodium malariae trophozoites

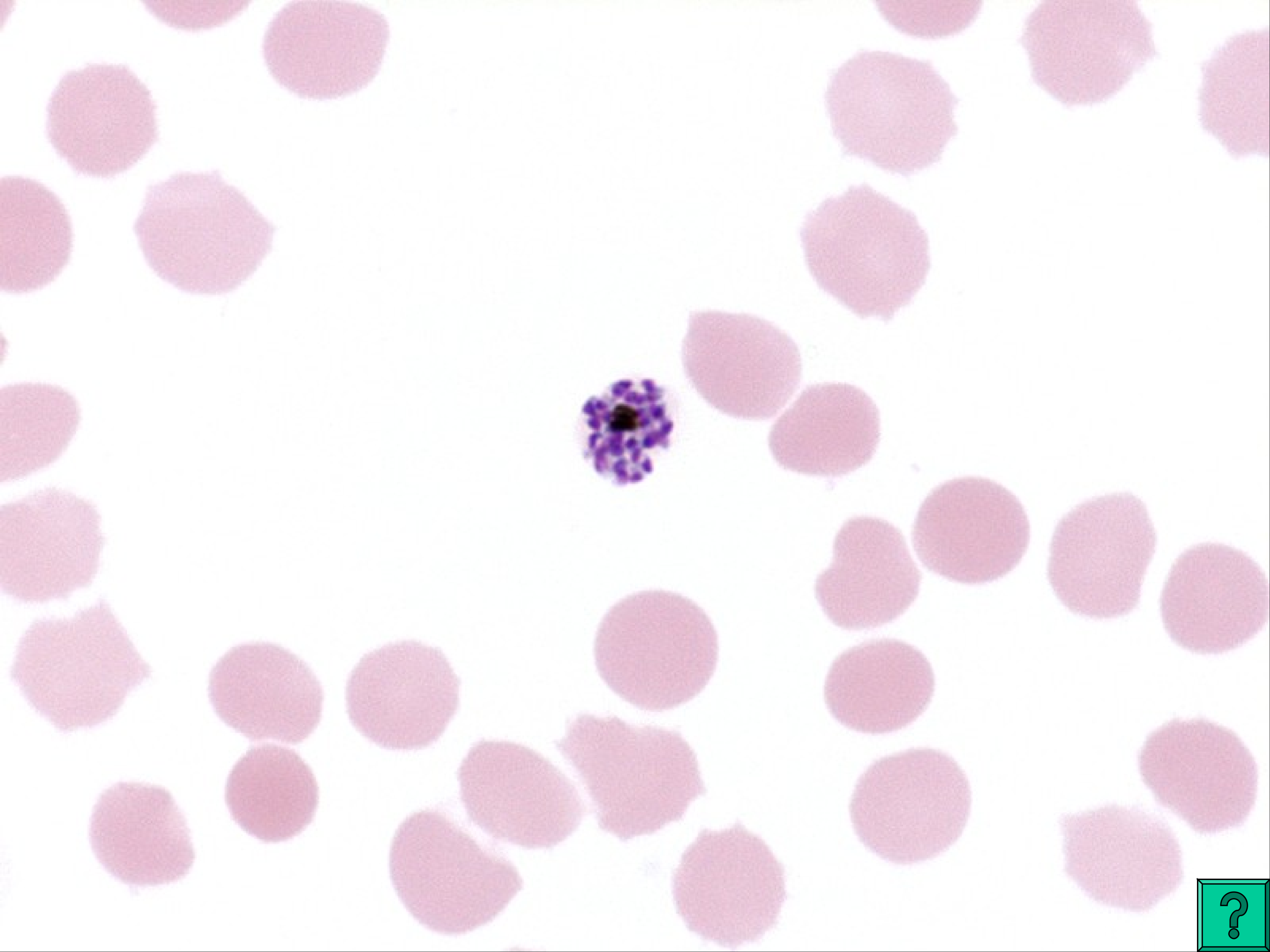
- band shape
- prominent hemozoin granules
- no Schüffner's dots
- infected RBC not enlarged or decolorized



SECTION OF HEART

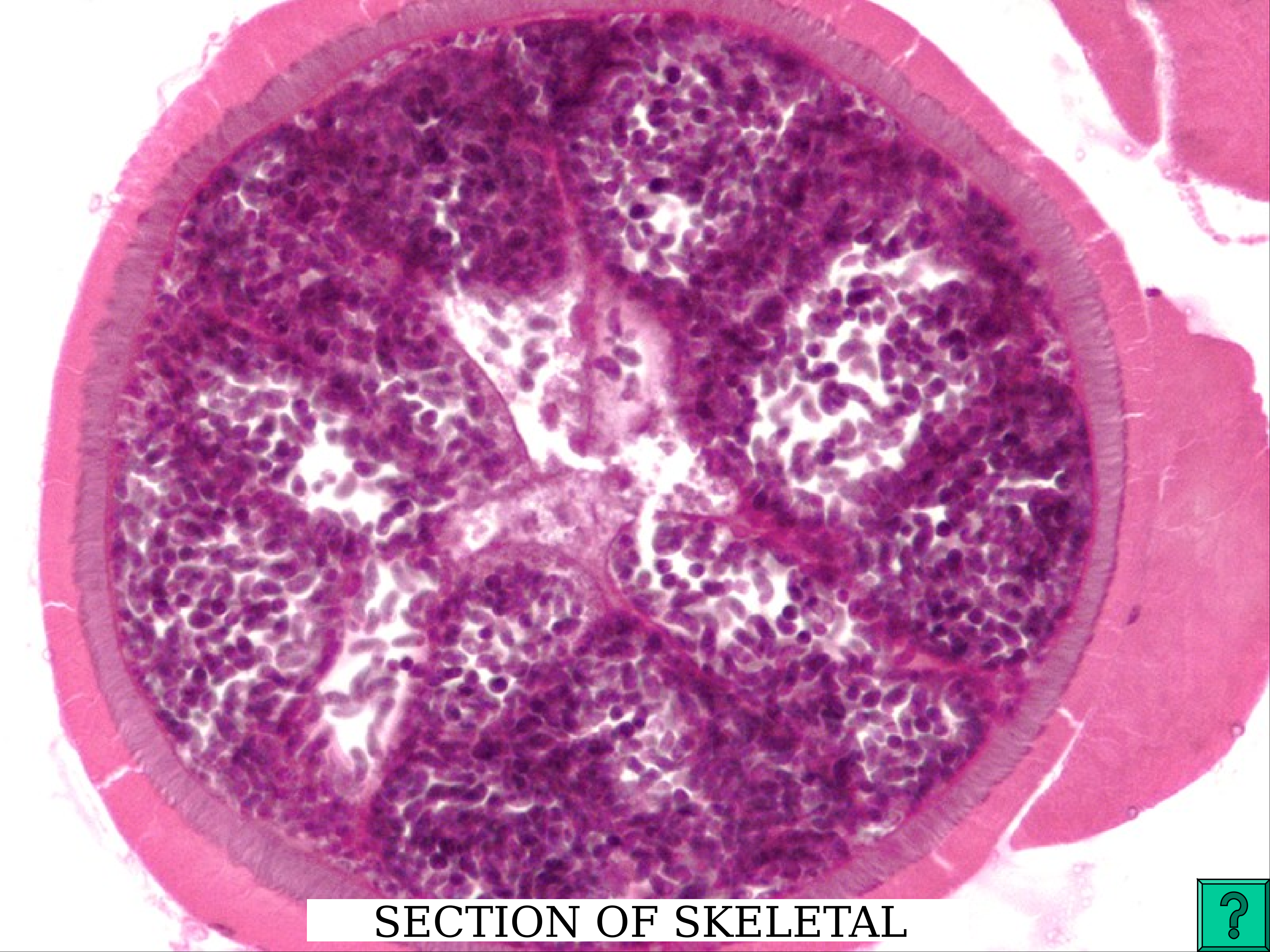
Trypanosoma cruzi pseudocyst

- intracellular amastigotes in cardiac myofibers, with recognizable nuclei and kinetoplasts
- inflammation and necrosis at sites of ruptured host cells



Plasmodium falciparum erythrocytic schizont

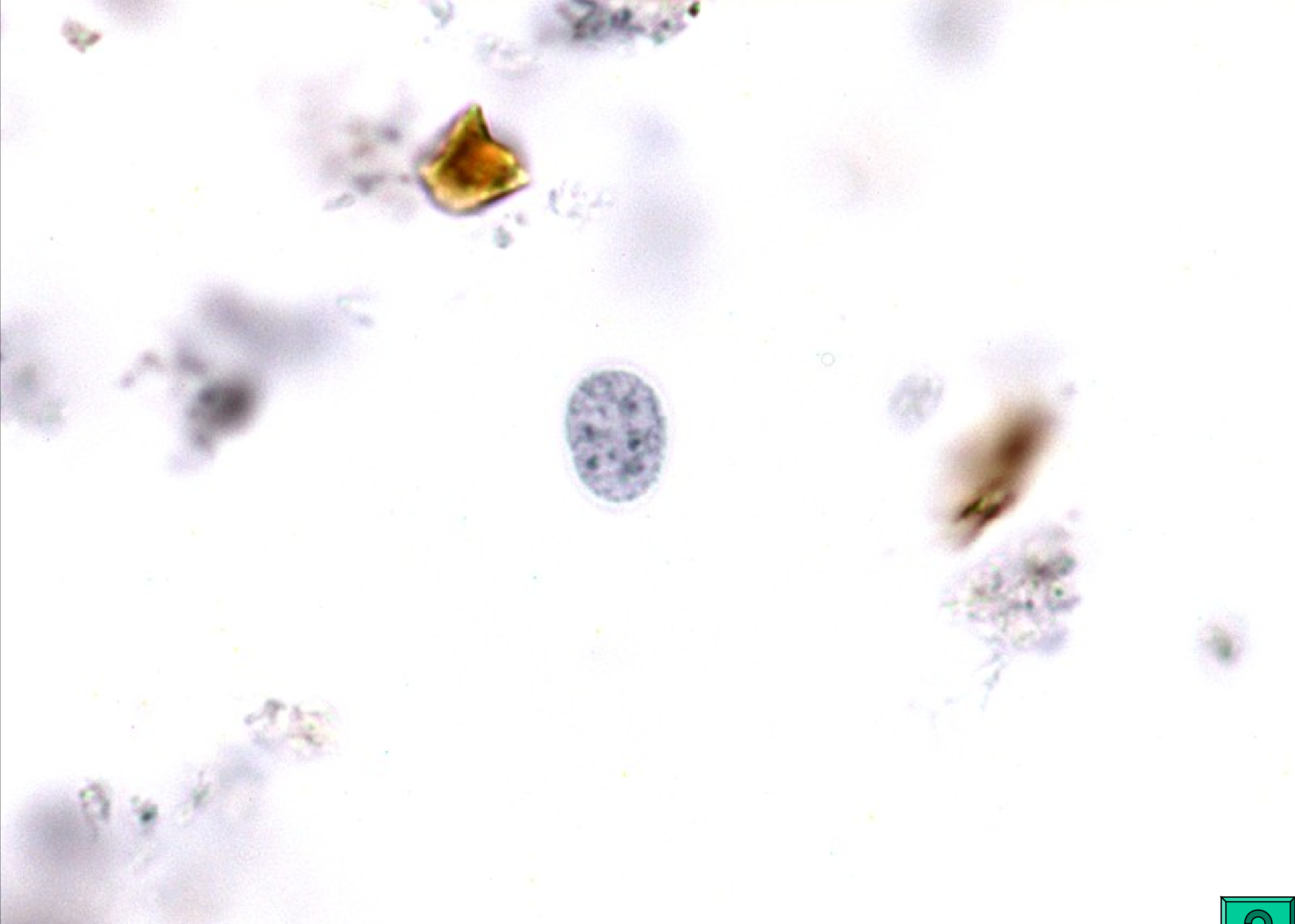
- approximately 20 merozoites/schizont
- very small merozoites
- hemozoin clumped in center



SECTION OF SKELETAL

Sarcocystis sp. zoitocyst (sarcocyst)

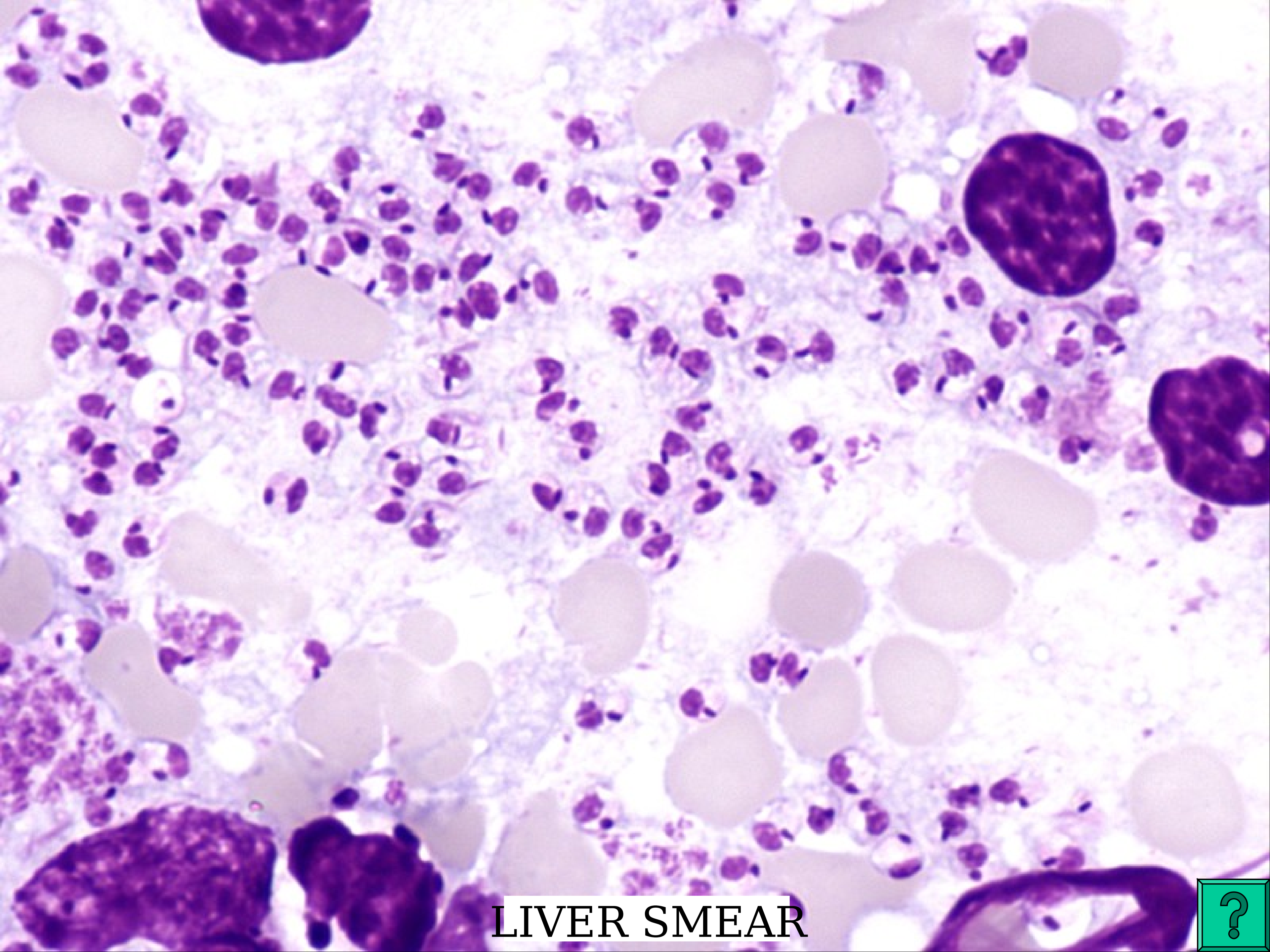
- large
- compartmentalized internally by septa
- contains bradyzoites
- radial striations in cyst wall



FECAL SPECIMEN

Endolimax nana cyst

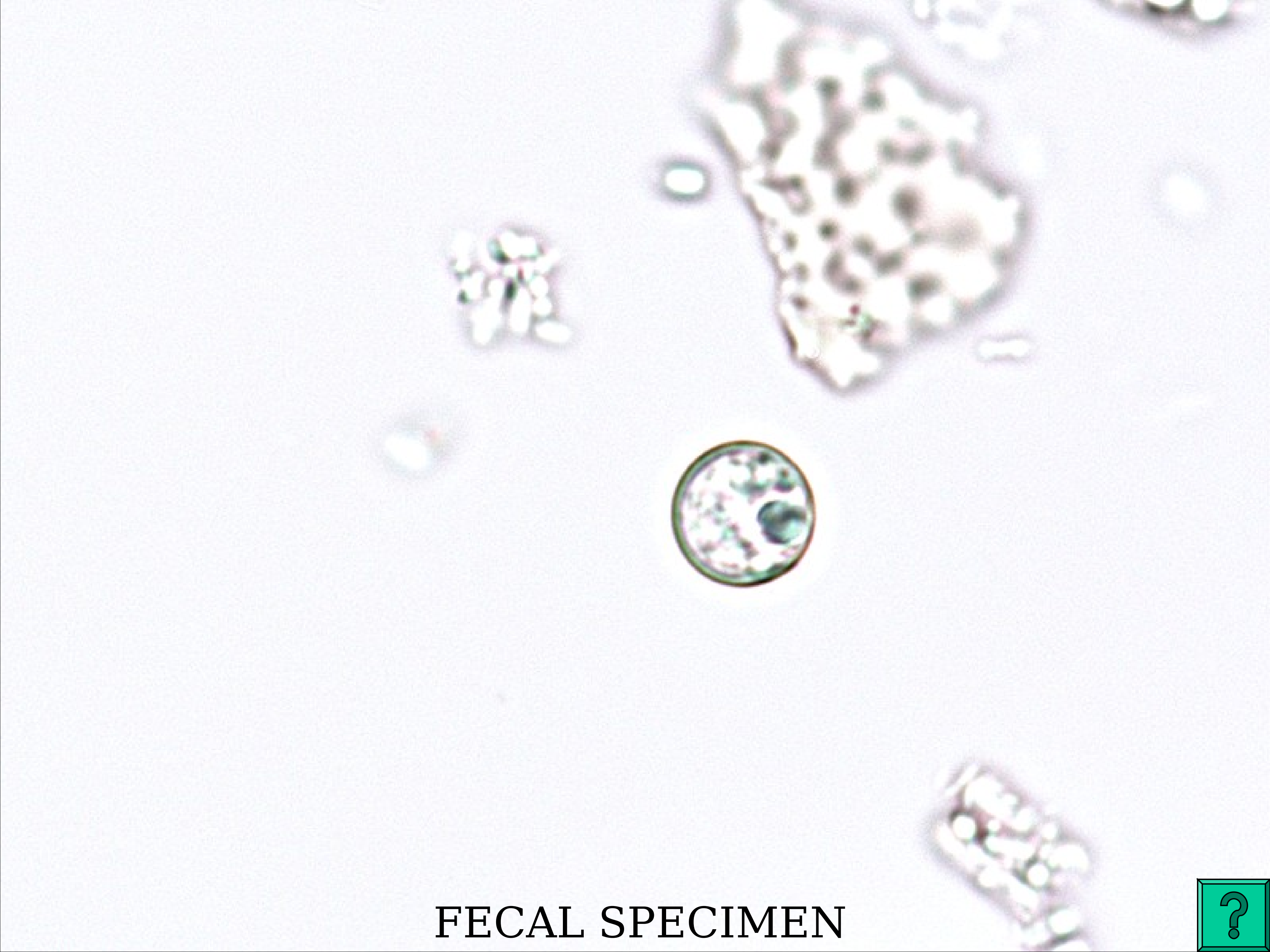
- small
- 4 nuclei
- large nuclear endosomes
- no peripheral chromatin granules



LIVER SMEAR

Leishmania donovani (or *Trypanosoma cruzi*) amastigotes

- small
- oval
- intracellular
- single nucleus and kinetoplast

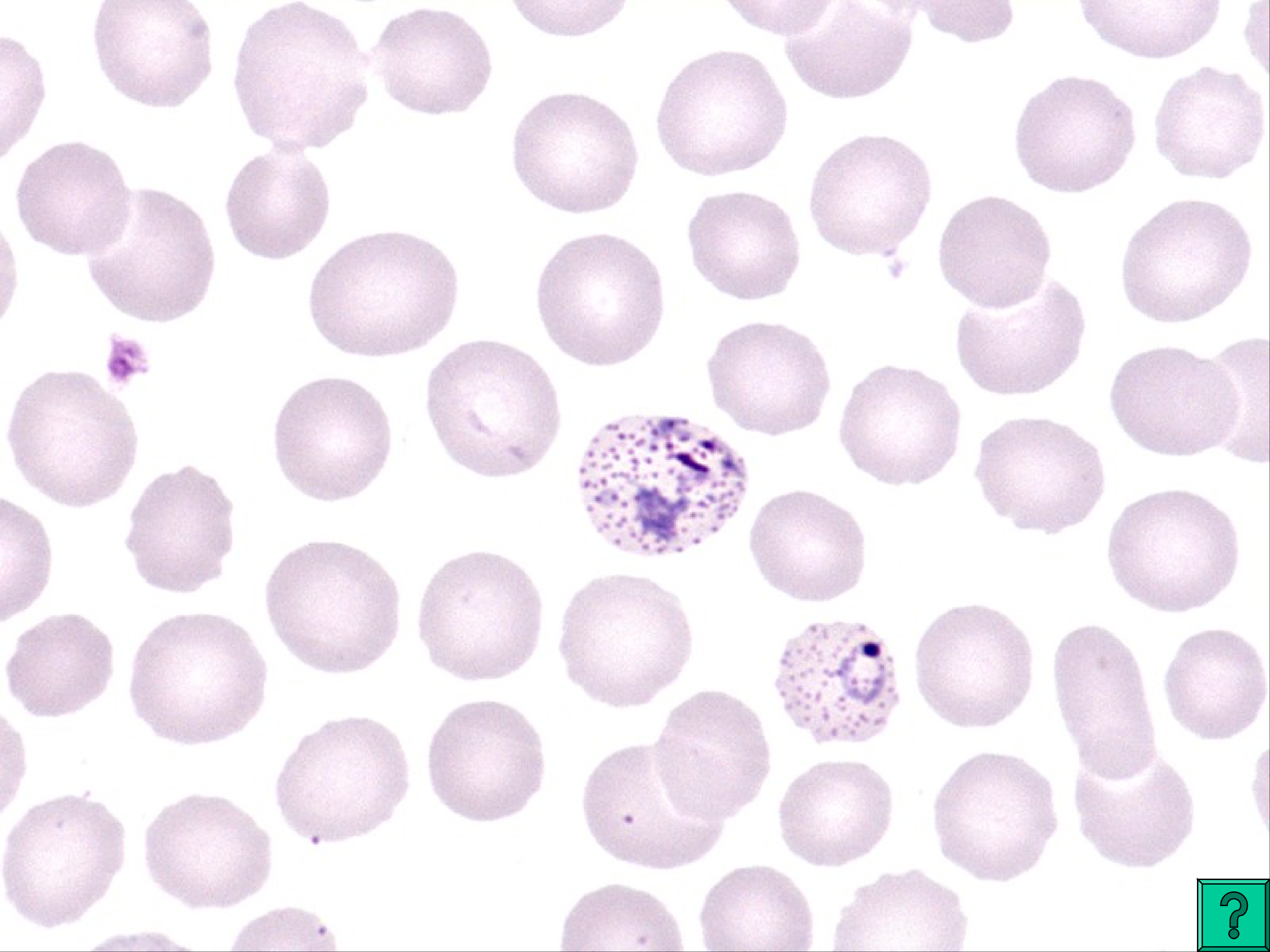


FECAL SPECIMEN

Cyclospora cayetanensis oocyst

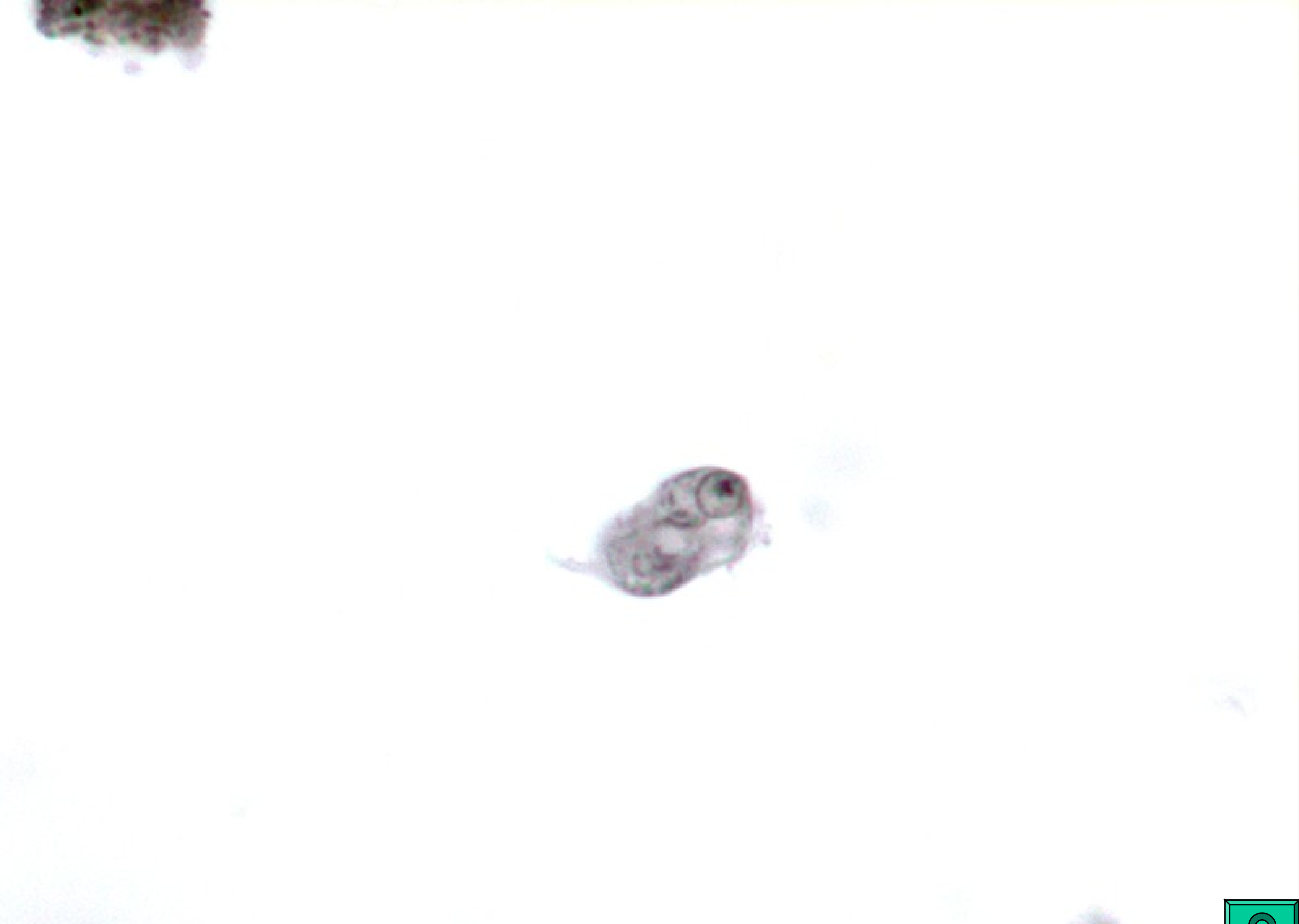
- round
- unsporulated
- globular contents
- thin walled
- larger than oocyst of *Cryptosporidium parvum*

⏮ ↩ ◀ ▶



Plasmodium vivax trophozoites

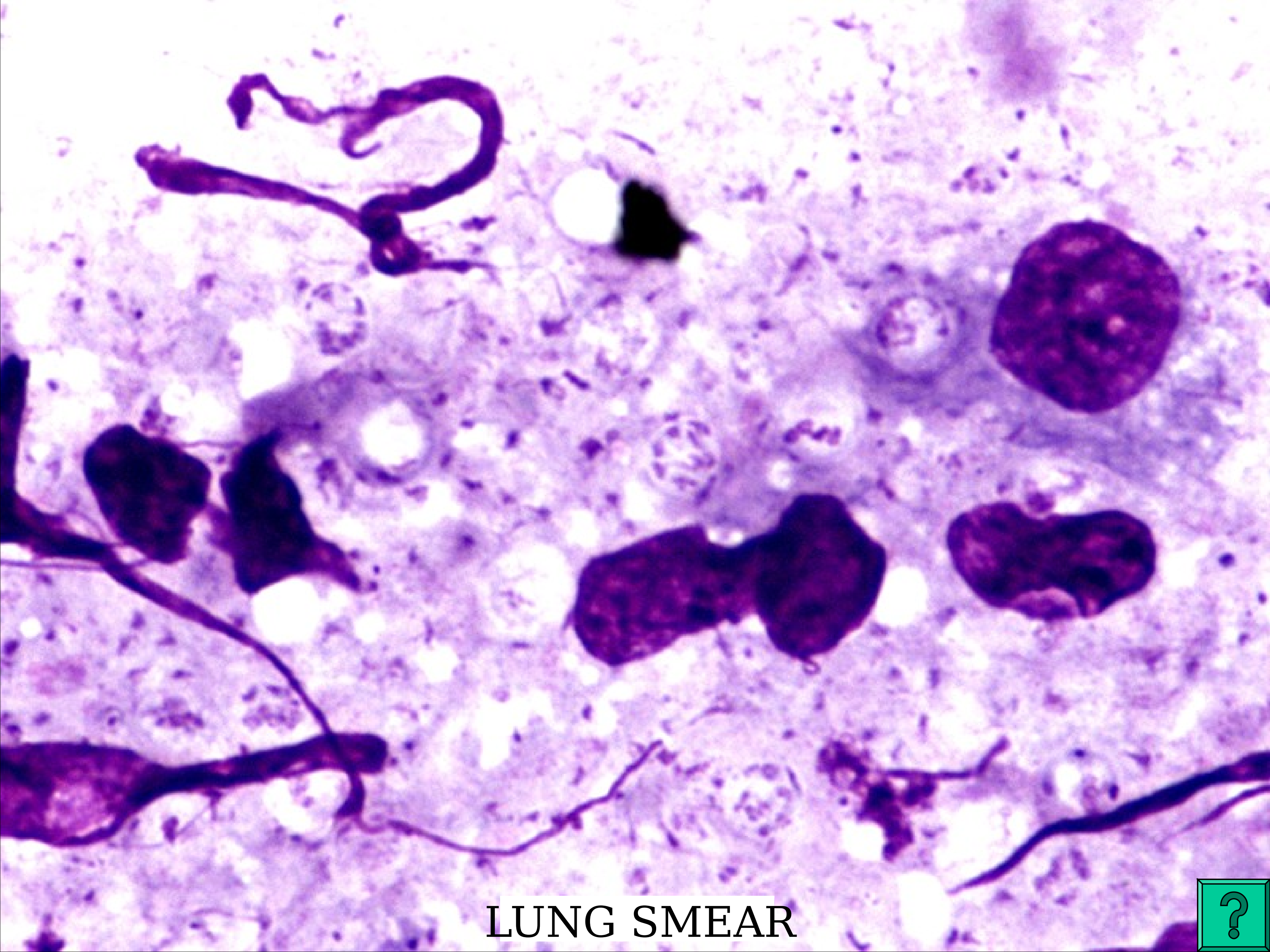
- ameboid trophozoite
- enlarged, decolorized RBCs
- prominent Schüffner’s dots
- hemozoin granules relatively inconspicuous



FECAL SPECIMEN

Chilomastix mesnili trophozoite

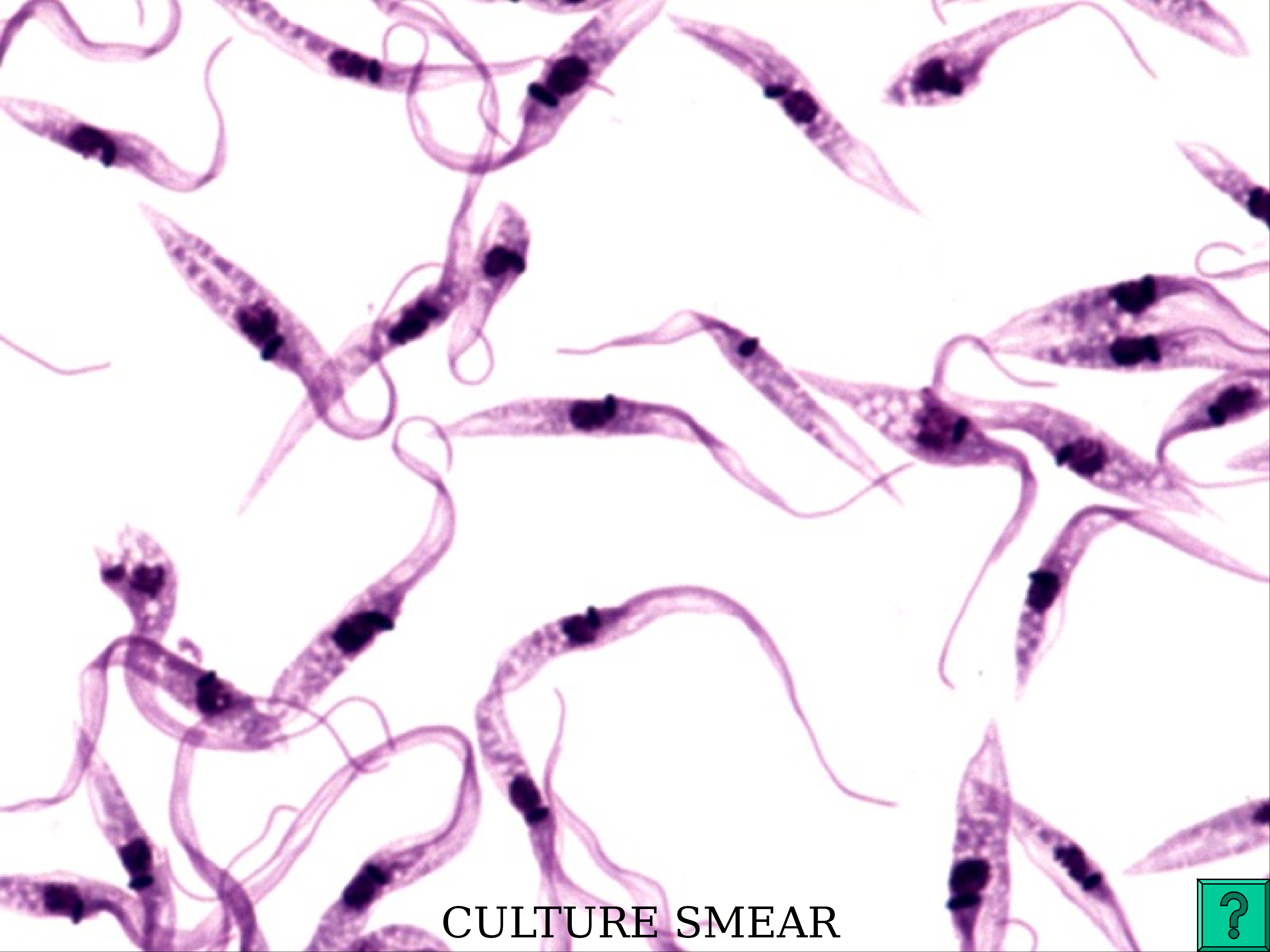
- single nucleus at anterior end
- blunt anterior end, pointed posterior end
- cytostomal groove



LUNG SMEAR

Pneumocystis carinii cysts

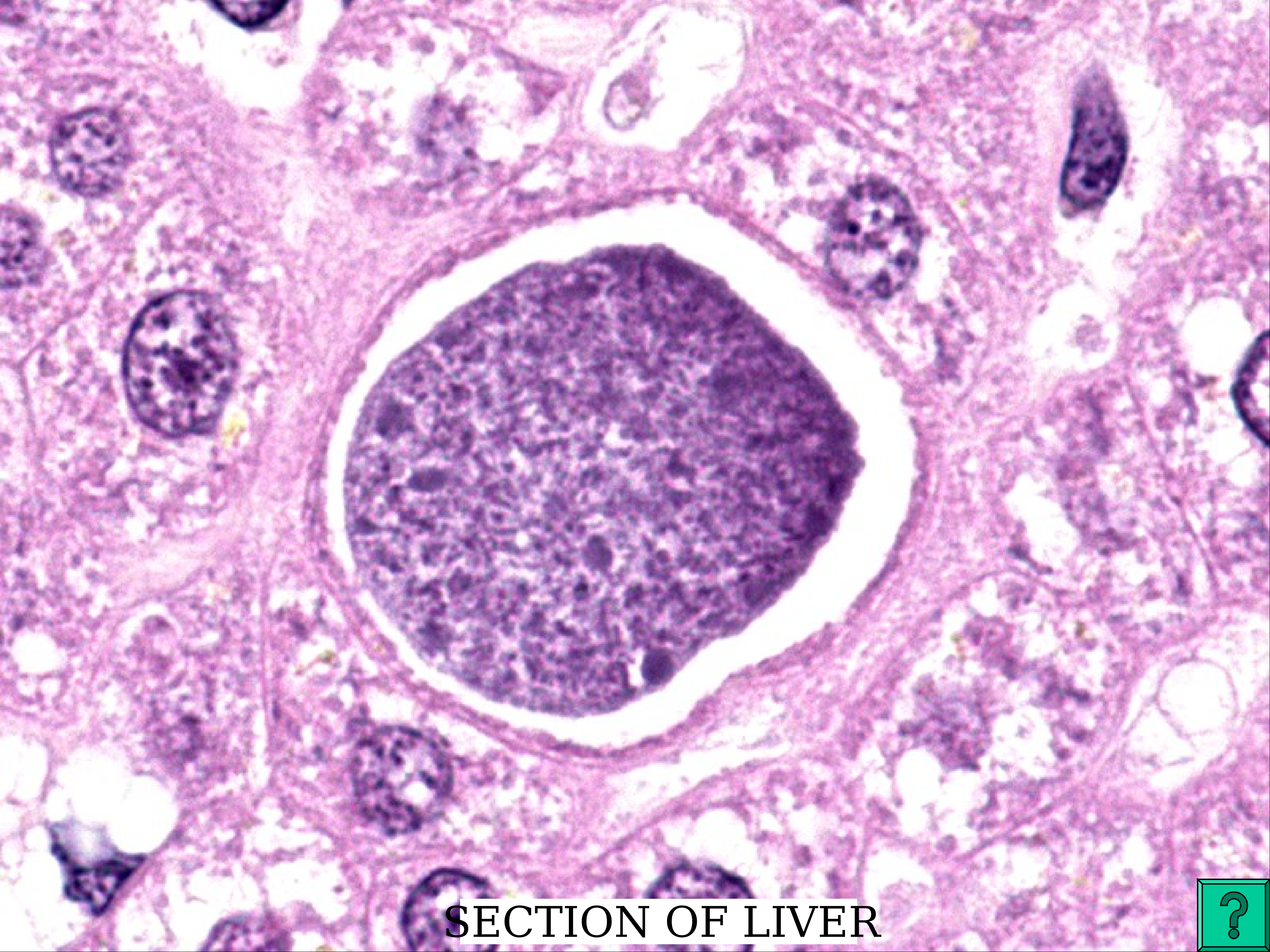
- spherical
- 8 intracystic bodies
- cyst wall unstained with Giemsa stain



CULTURE SMEAR

Trypanosoma cruzi (or *Trypanosoma* spp.) epimastigotes

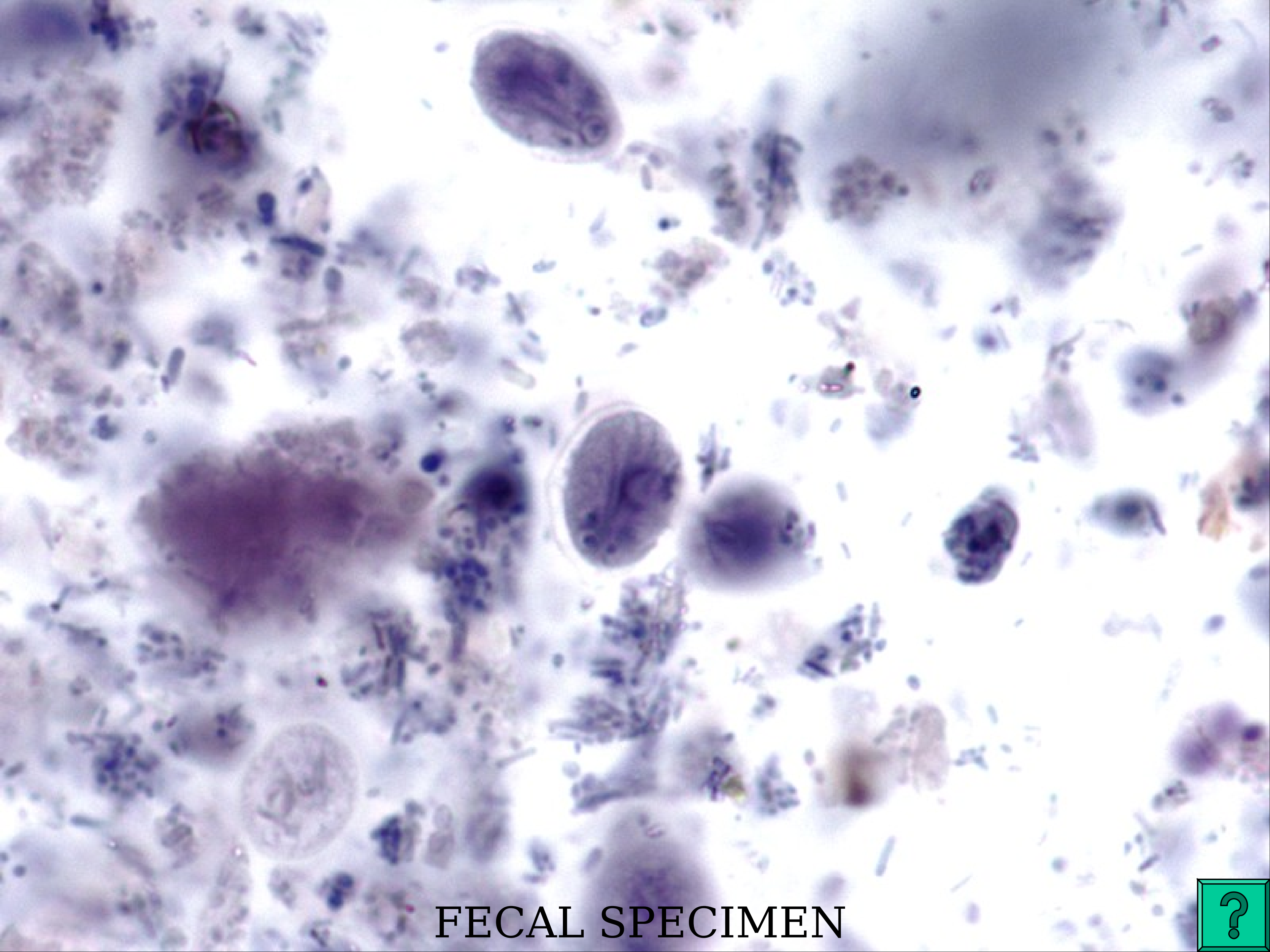
- undulating membrane
- free flagellum
- kinetoplast anterior to nucleus



SECTION OF LIVER

Plasmodium sp. exoerythrocytic schizont

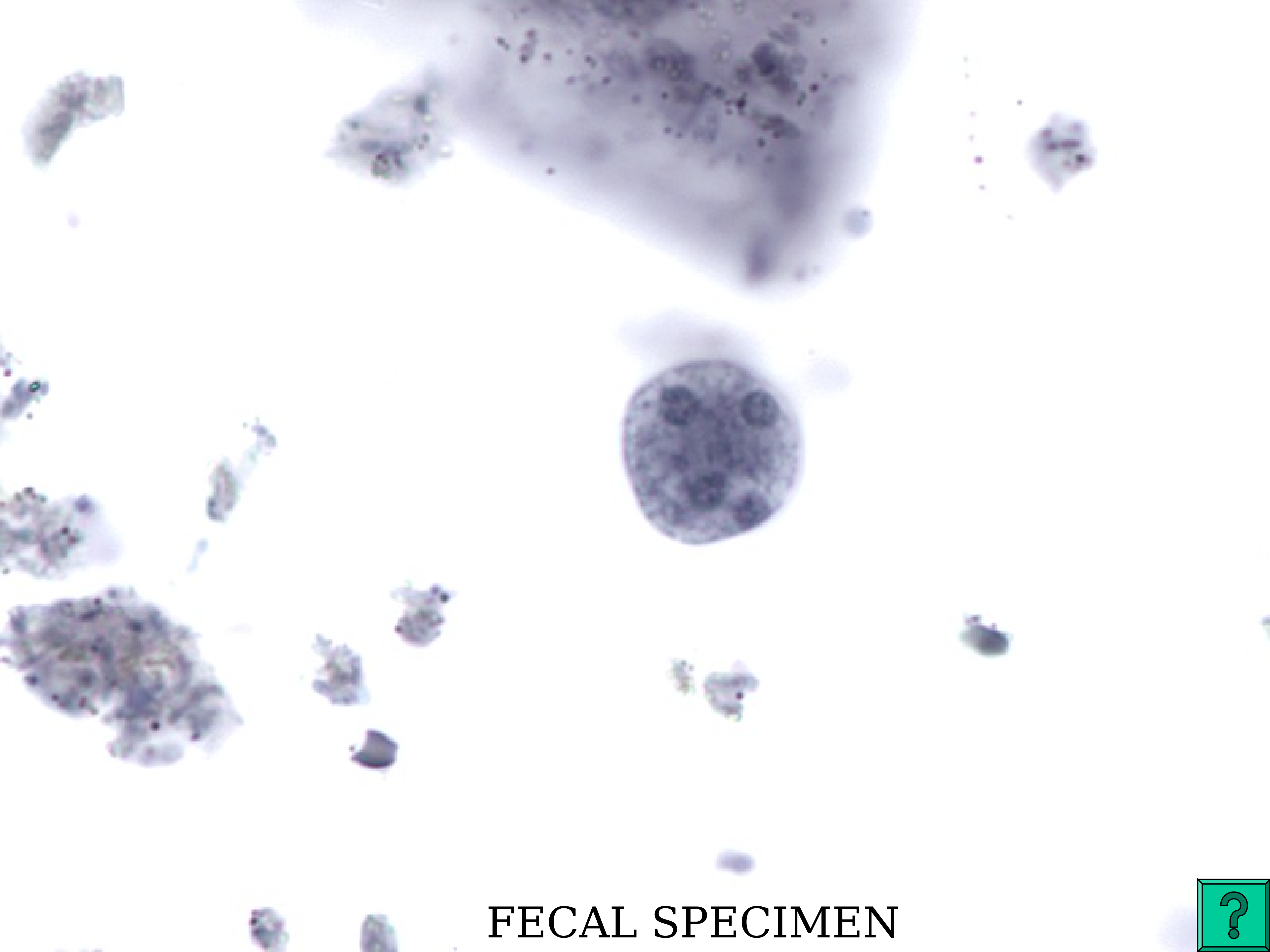
- intracellular
- many (thousands) of nuclei
- no inflammation



FECAL SPECIMEN

Giardia lamblia cysts

- oval
- 4 nuclei (3 are visible), with endosomes
- axonemes visible
- often a clear space between cell and cyst wall

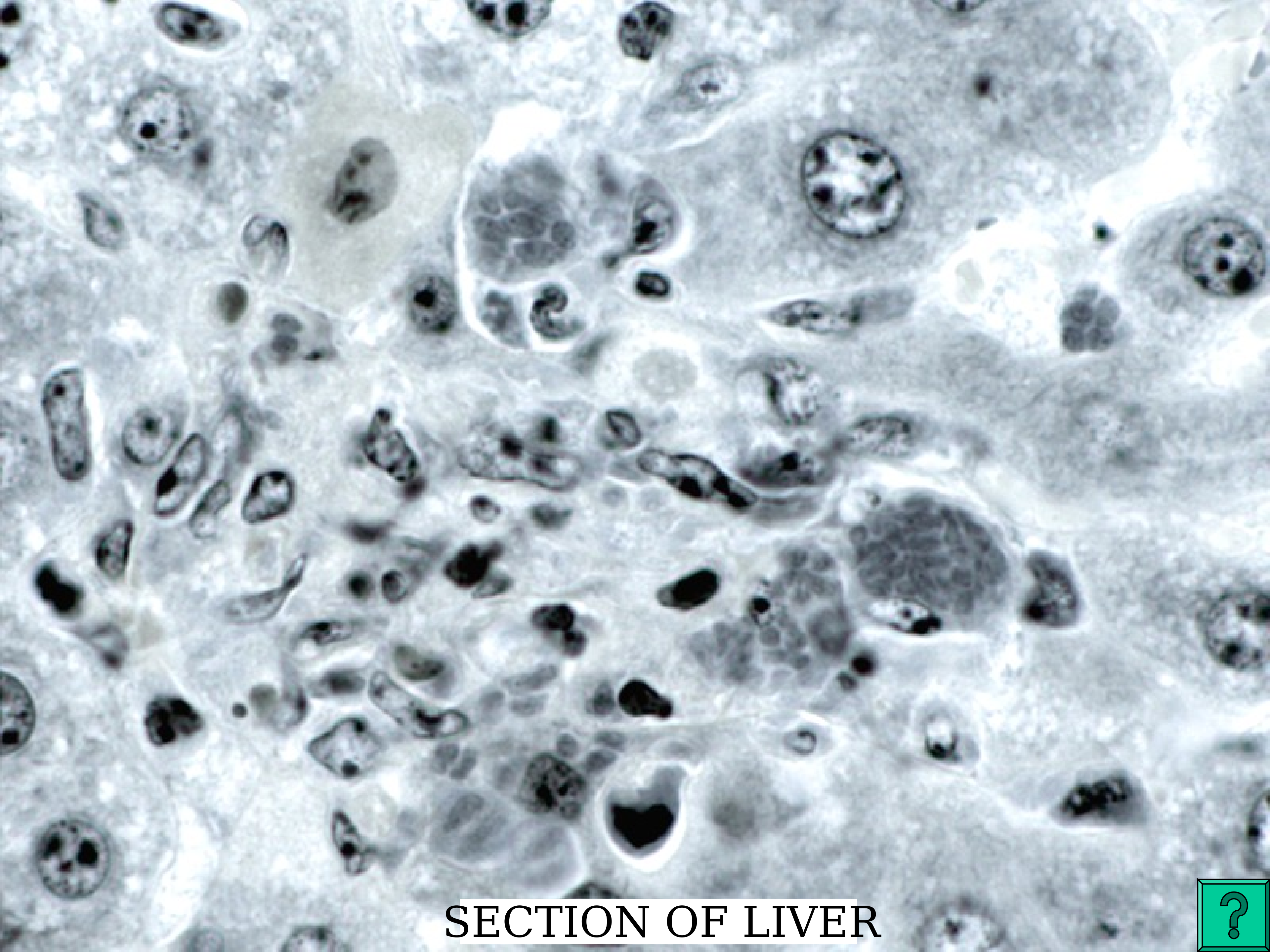


FECAL SPECIMEN

Entamoeba histolytica cyst

- spherical to oval
- 4 nuclei
- small, discrete, centrally located nuclear endosome (not apparent here)
- fine granules of peripheral chromatin
- finely granular cytoplasm

⏮ ↺ ◁ ▷

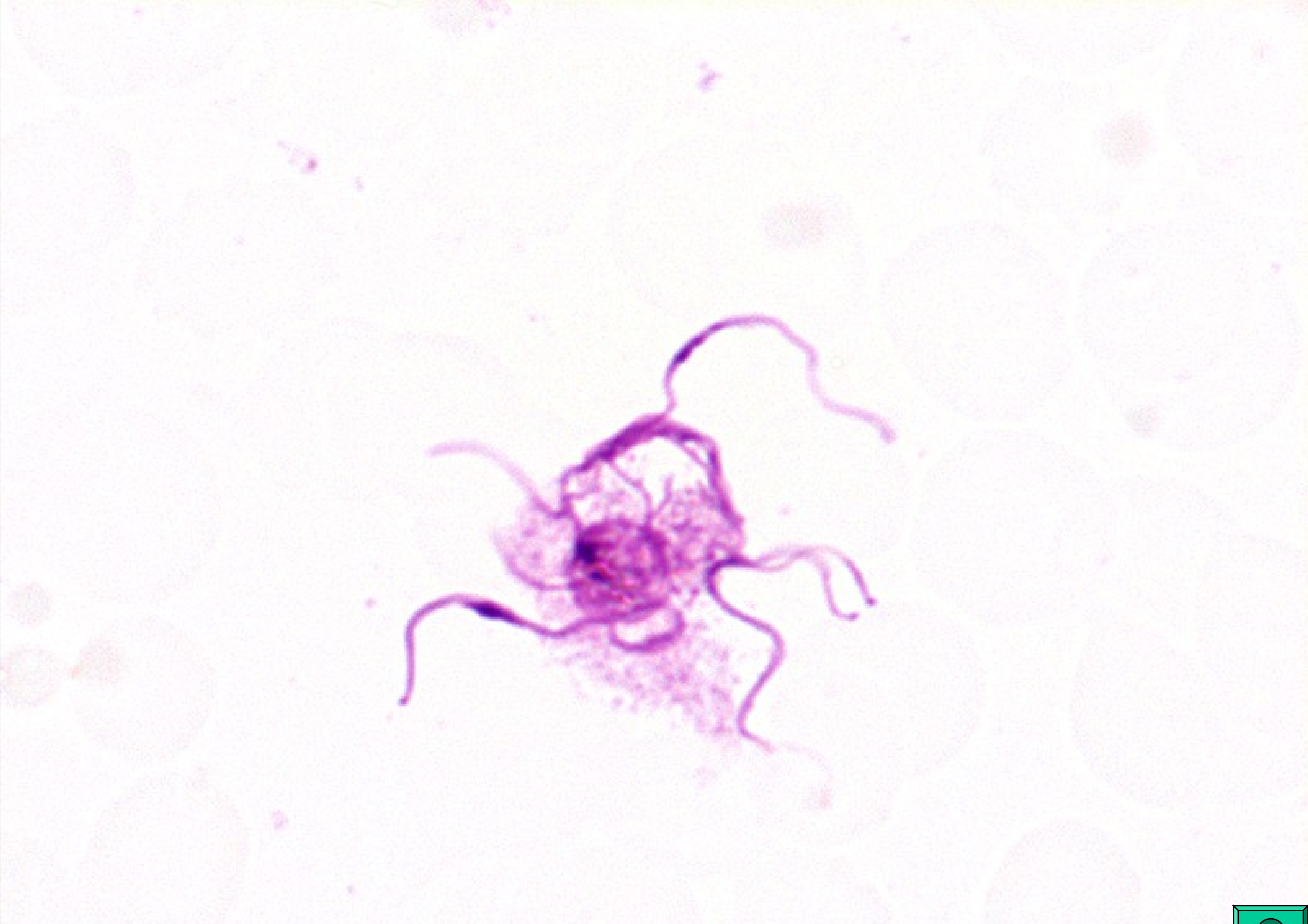


SECTION OF LIVER

Toxoplasma gondii tachyzoites

- intracellular merozoites
- small number (8 to 32)/cell
- no kinetoplast

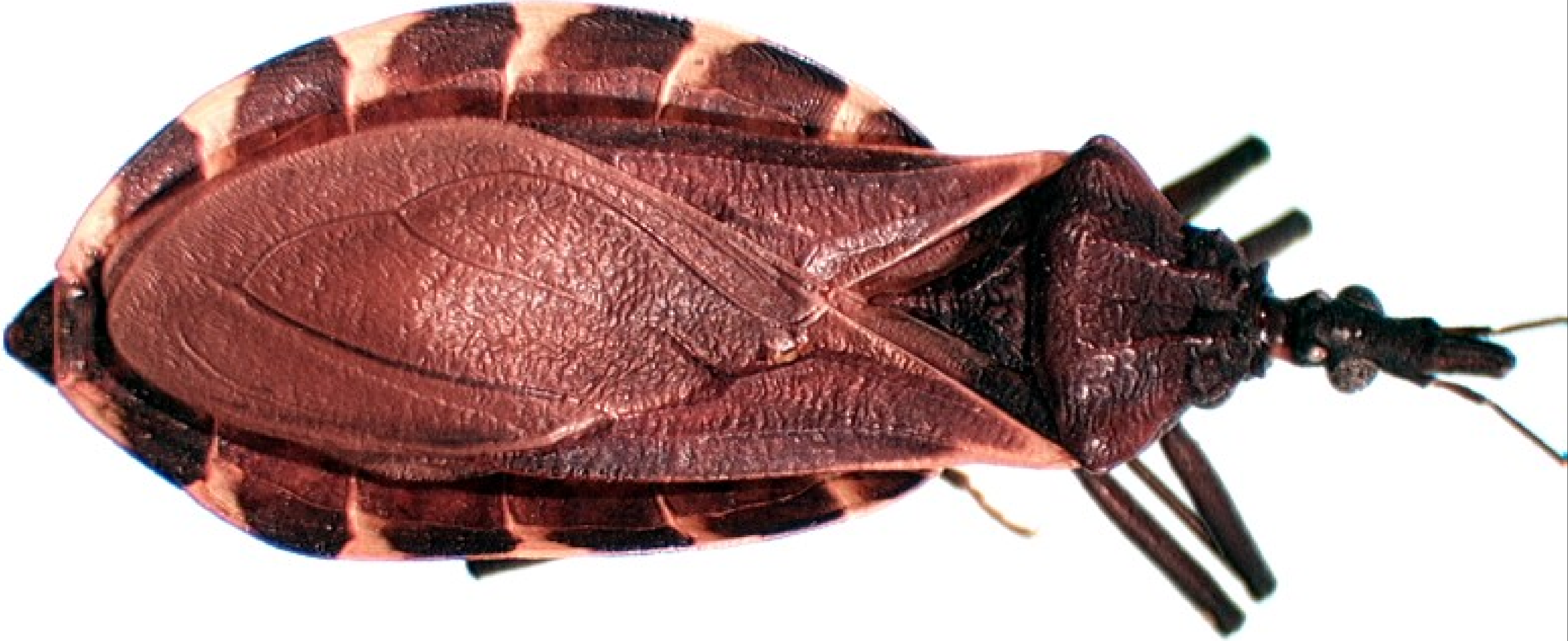
⏮ ↺ ◁ ▷



SQUASH OF MOSQUITO GUT

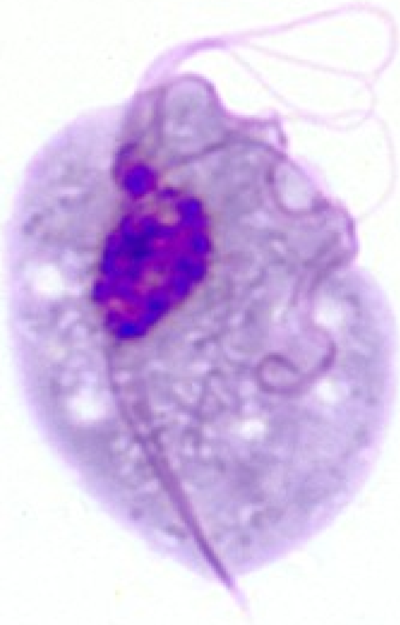
Plasmodium sp. microgametes (exflagellation)

- slender cells, consisting of an axoneme plus nucleus
- radial arrangement around remnant of microgametocyte



Reduviid kissing bug (*Triatoma gerstaeckeri*)

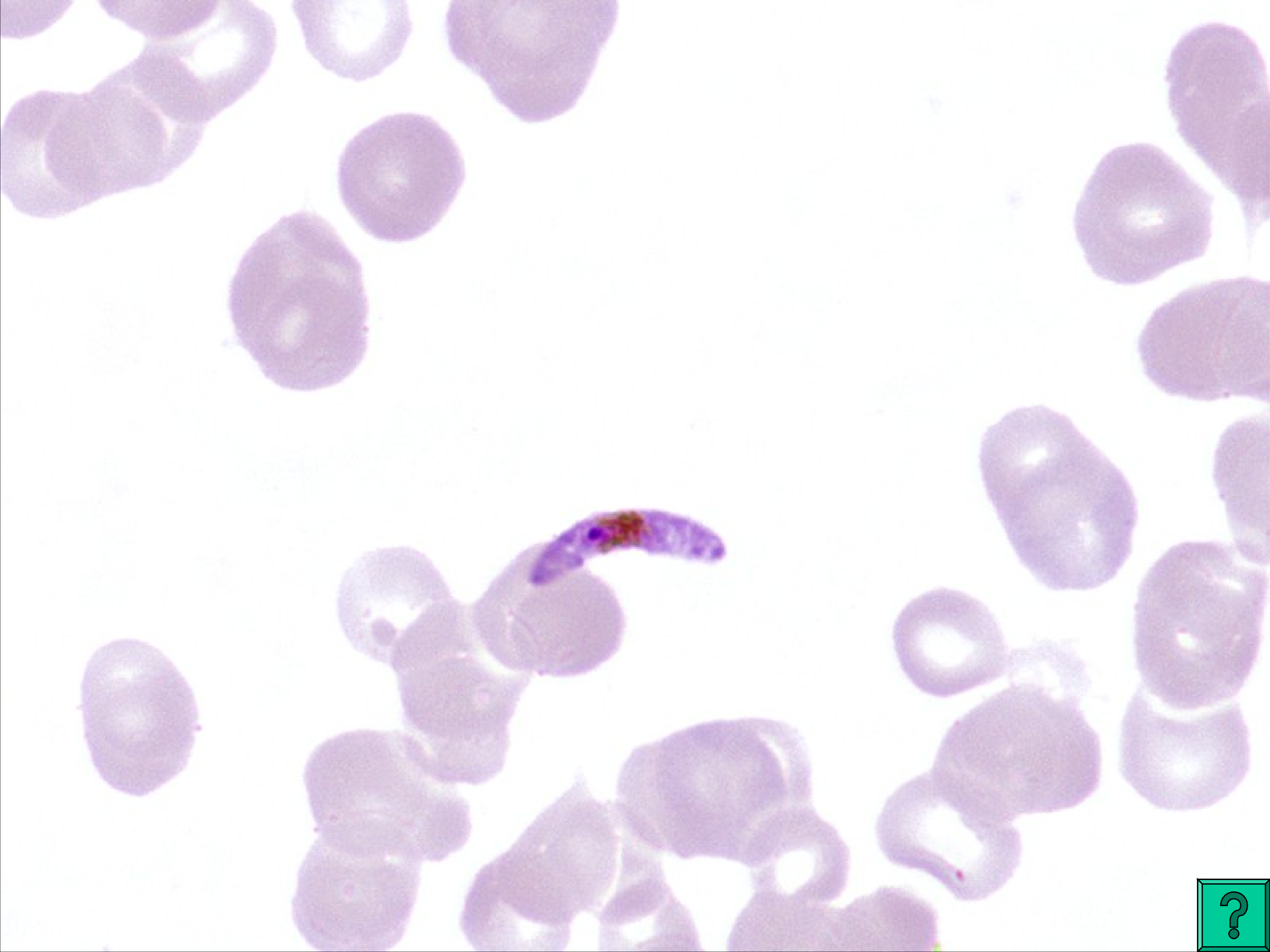
- large
- cone nosed with prominent eyes
- dorsoventrally flattened
- wings in concavity on top of abdomen
- edge of abdomen with orange stripes



URINE SEDIMENT

Trichomonas vaginalis trophozoite

- pyriform shape
- 4 anteriorly directed flagella
- 1 posteriorly directed flagellum as an undulating membrane
- nucleus, with evenly distributed chromatin, at anterior end
- axostyle protruding from posterior end



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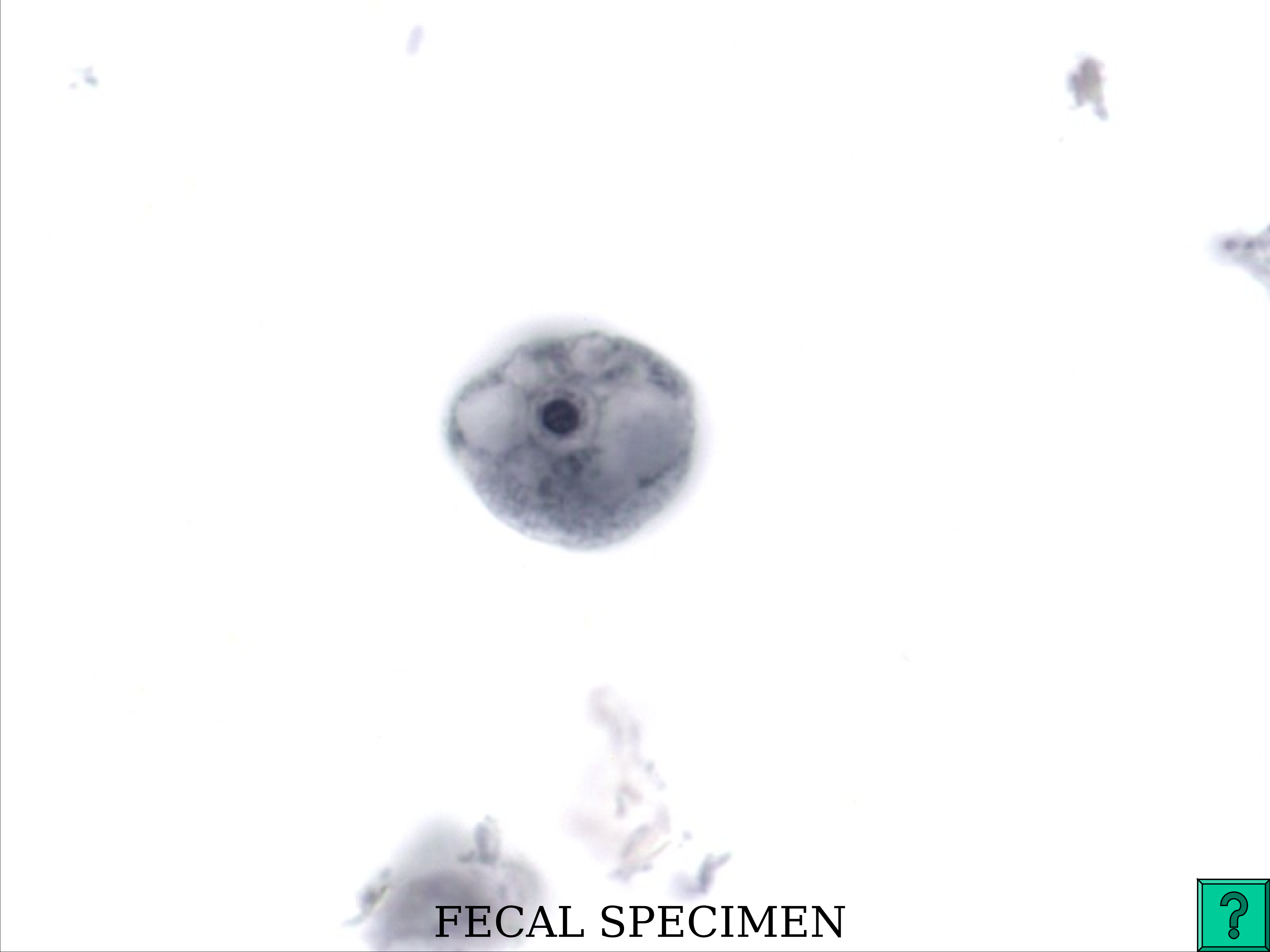
Plasmodium falciparum macrogametocyte

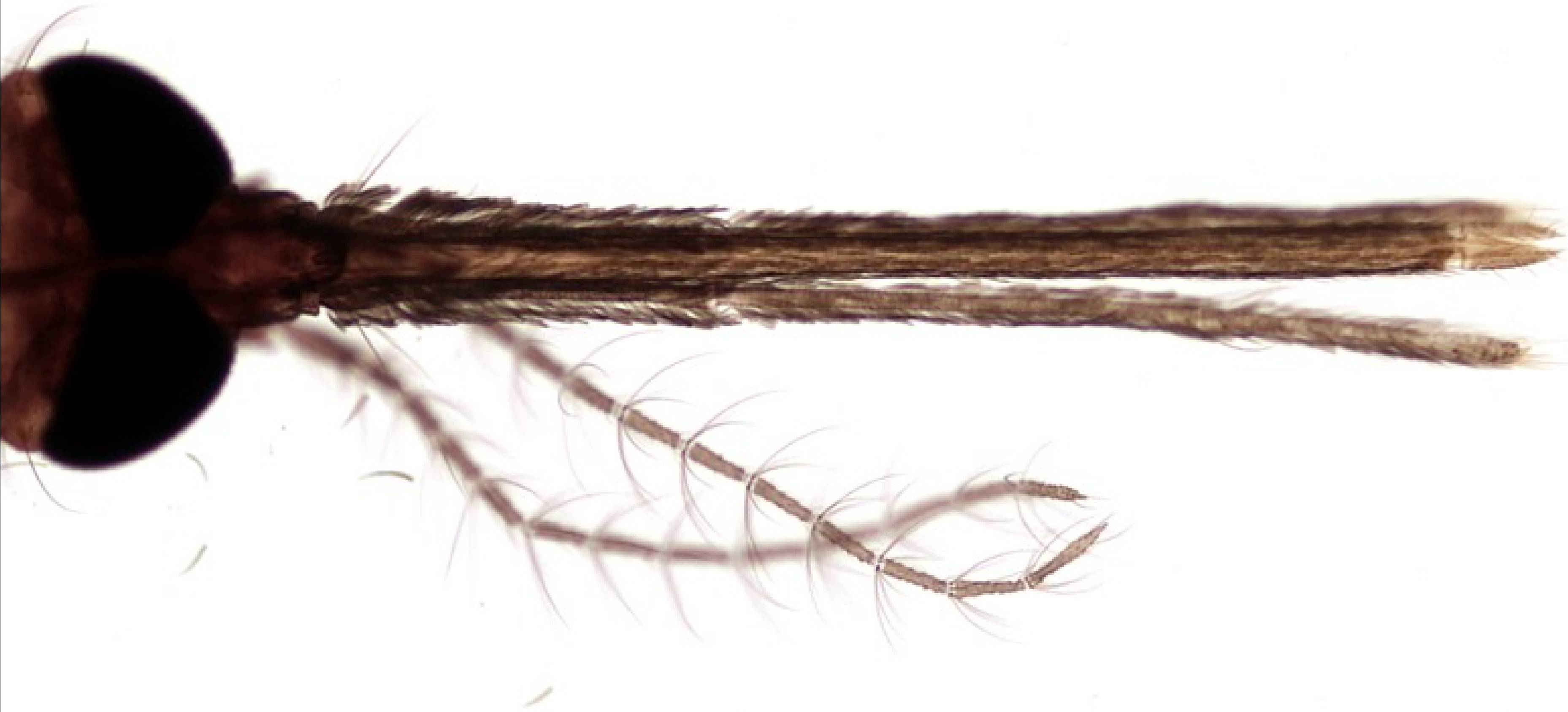
- elongate
- pointed ends
- nucleus < one half of cell length
- hemozoin granules around nucleus



FECAL SPECIMEN

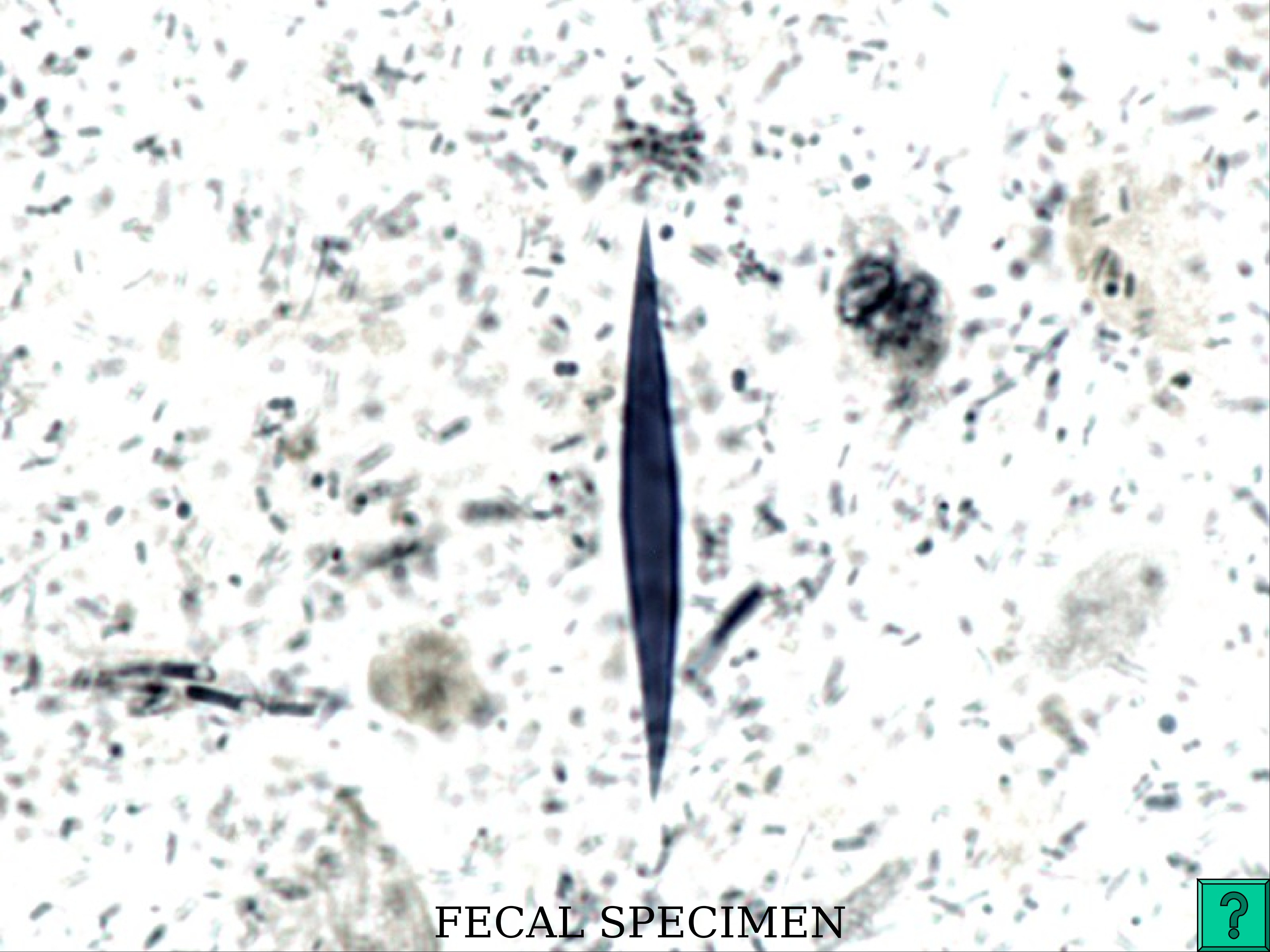
Iodamoeba butschlii trophozoite

- irregular shape
- large nuclear endosome
- no peripheral chromatin granules
- vacuolated cytoplasm
- food vacuoles with bacteria



Anopheles sp. female

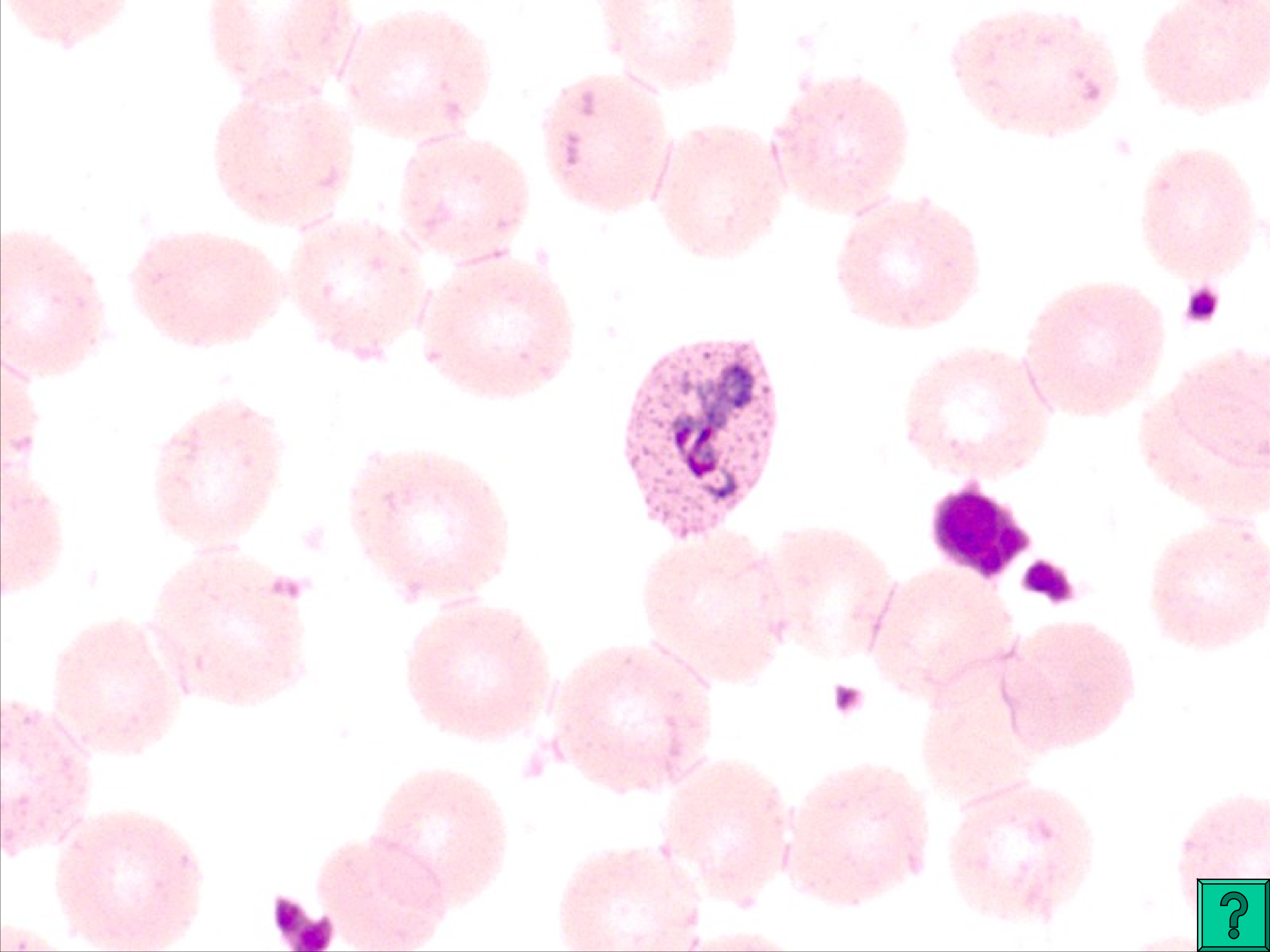
- palps almost same length as proboscis
- non plumose antennae



FECAL SPECIMEN

Charcot-Leyden crystal

- possible indicator of infection with *Entamoeba histolytica*

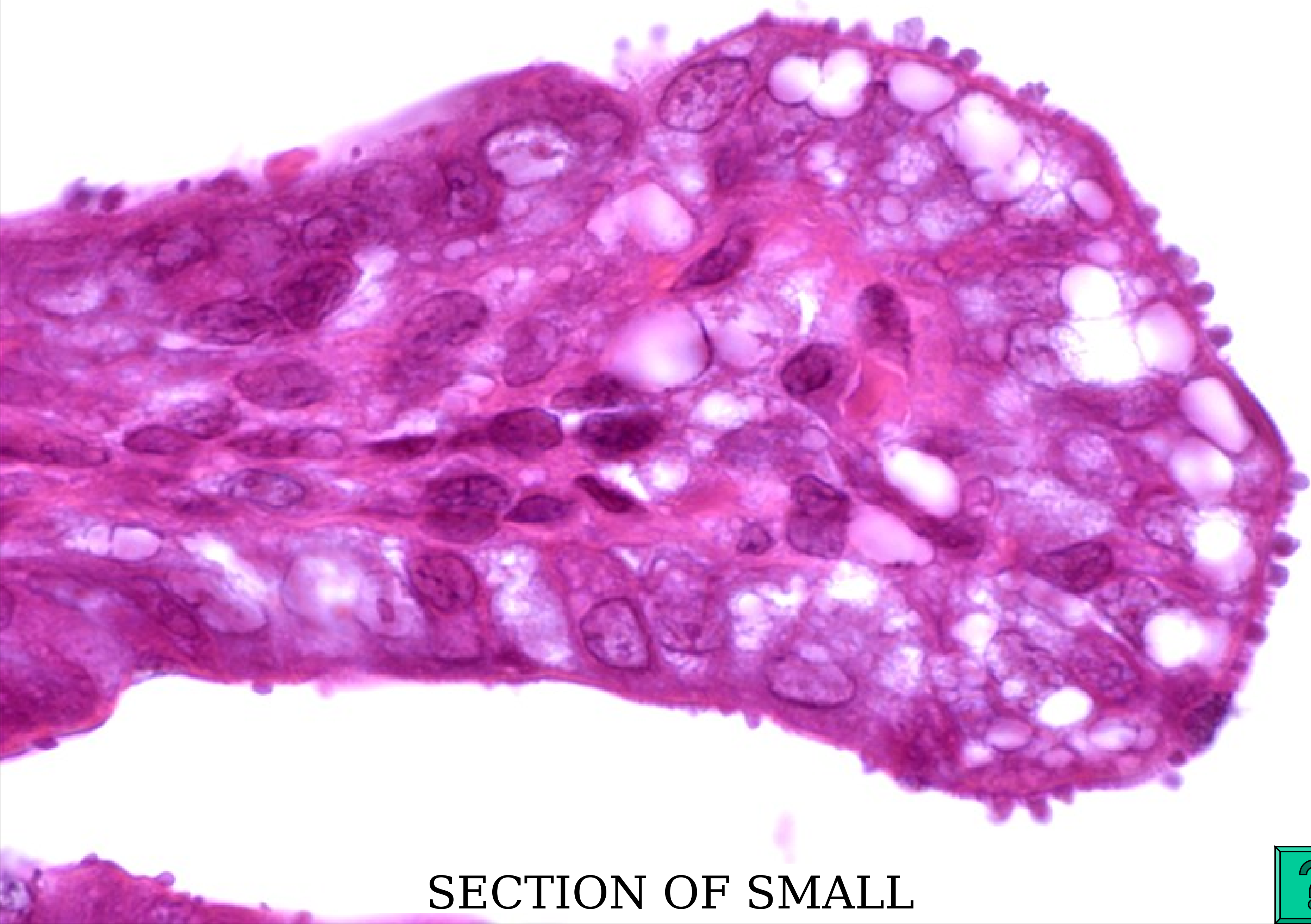


?

Plasmodium ovale trophozoite

- oval distortion of infected cell
- prominent Schüffner’s dots
- large chromatin mass
- enlarged RBC, with fimbriated edge

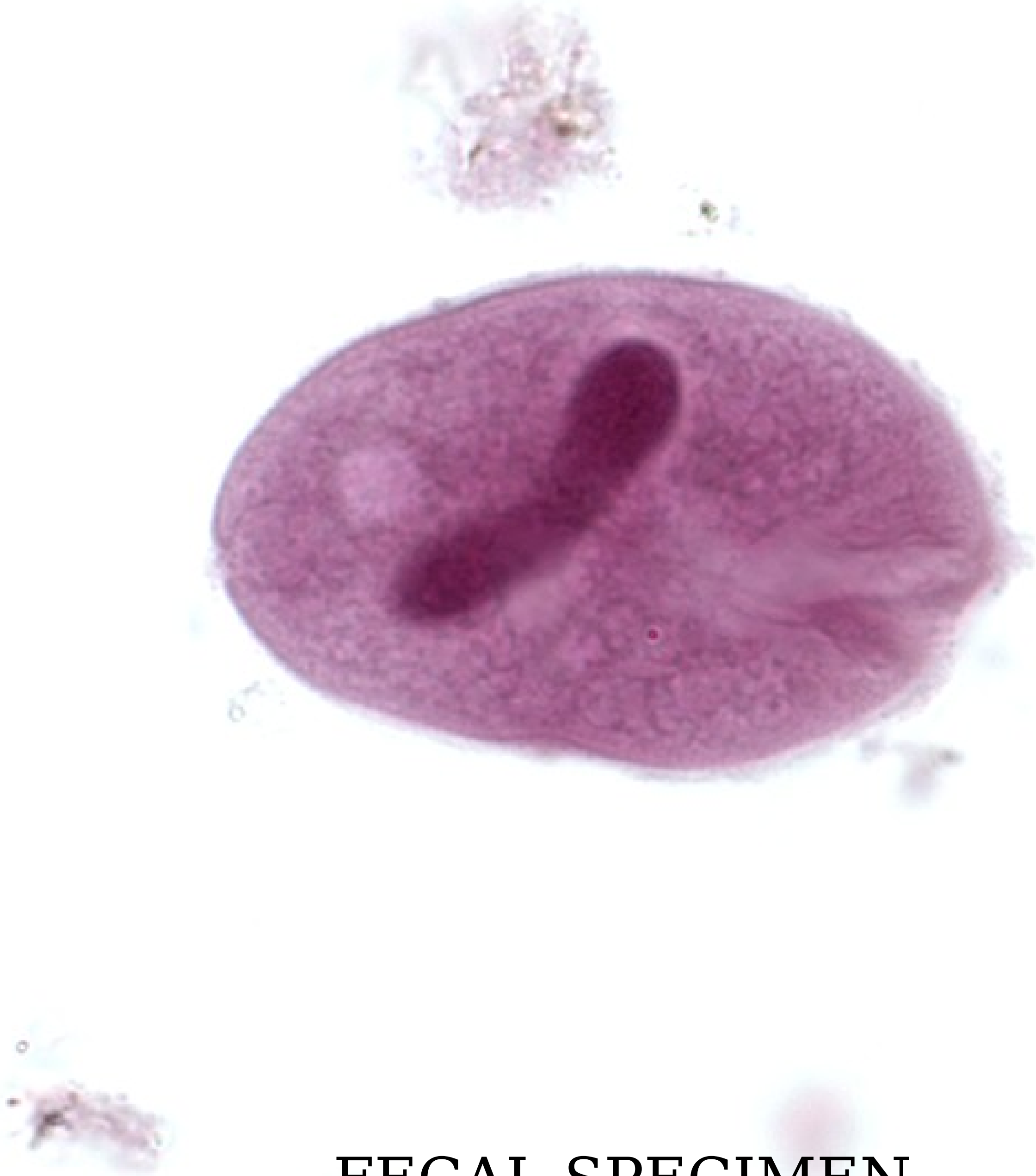
⏮ ↶ ◁ ▷



SECTION OF SMALL

Cryptosporidium parvum infection

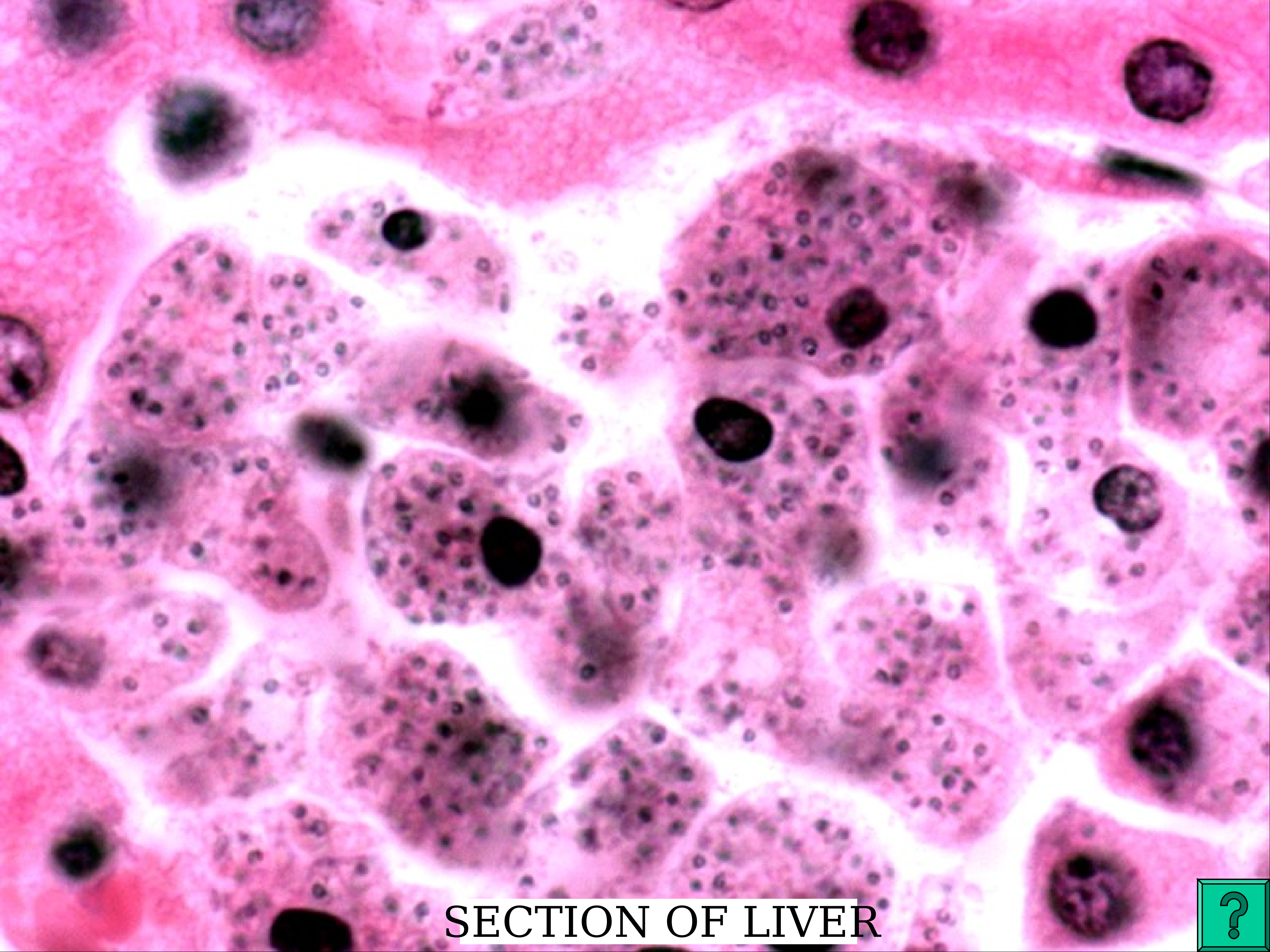
- round bodies (oocysts) in brush border



FECAL SPECIMEN

Balantidium coli trophozoite

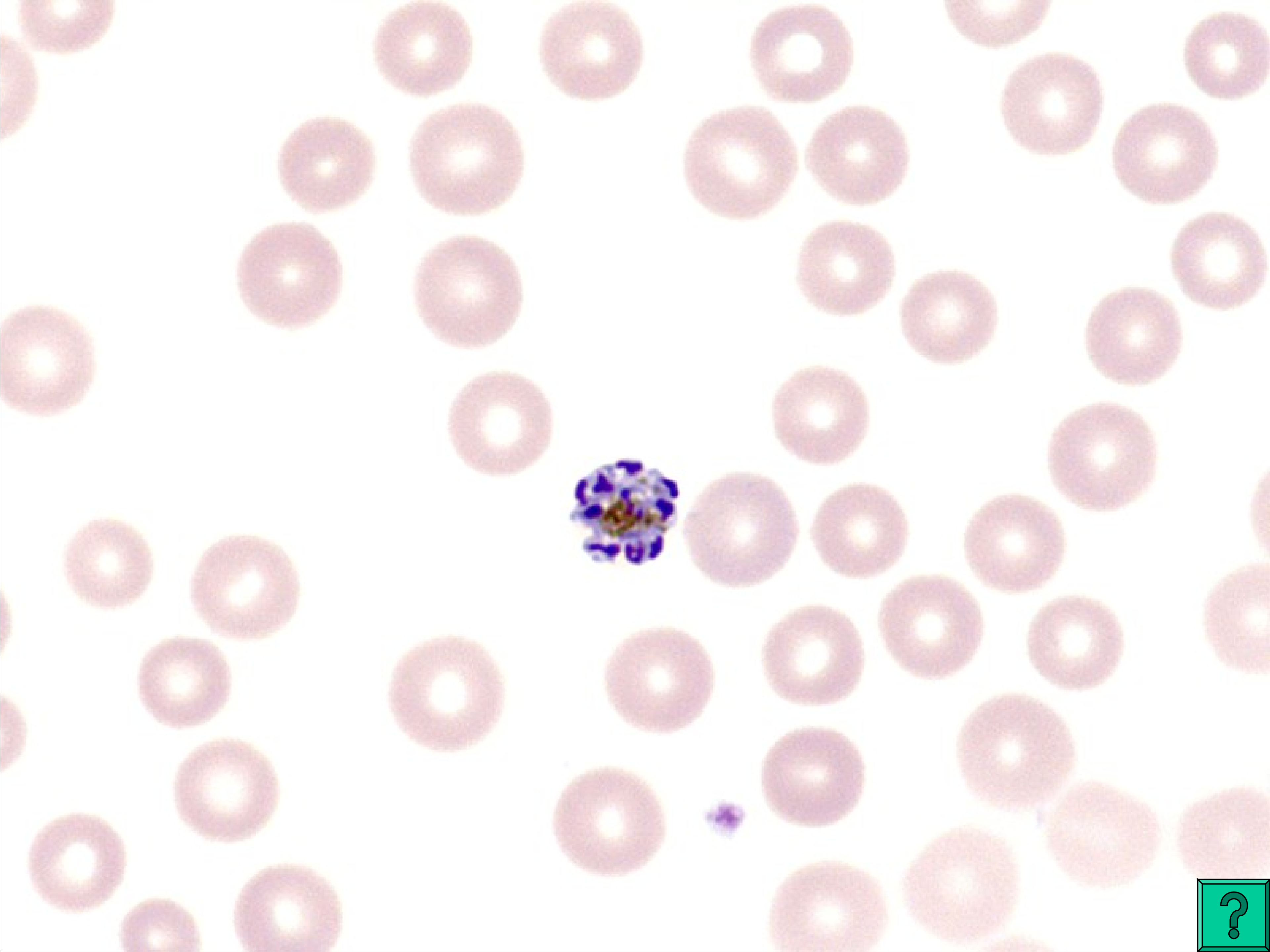
- large
- ciliated
- curved macronucleus
- cytostome
- food vacuoles



SECTION OF LIVER

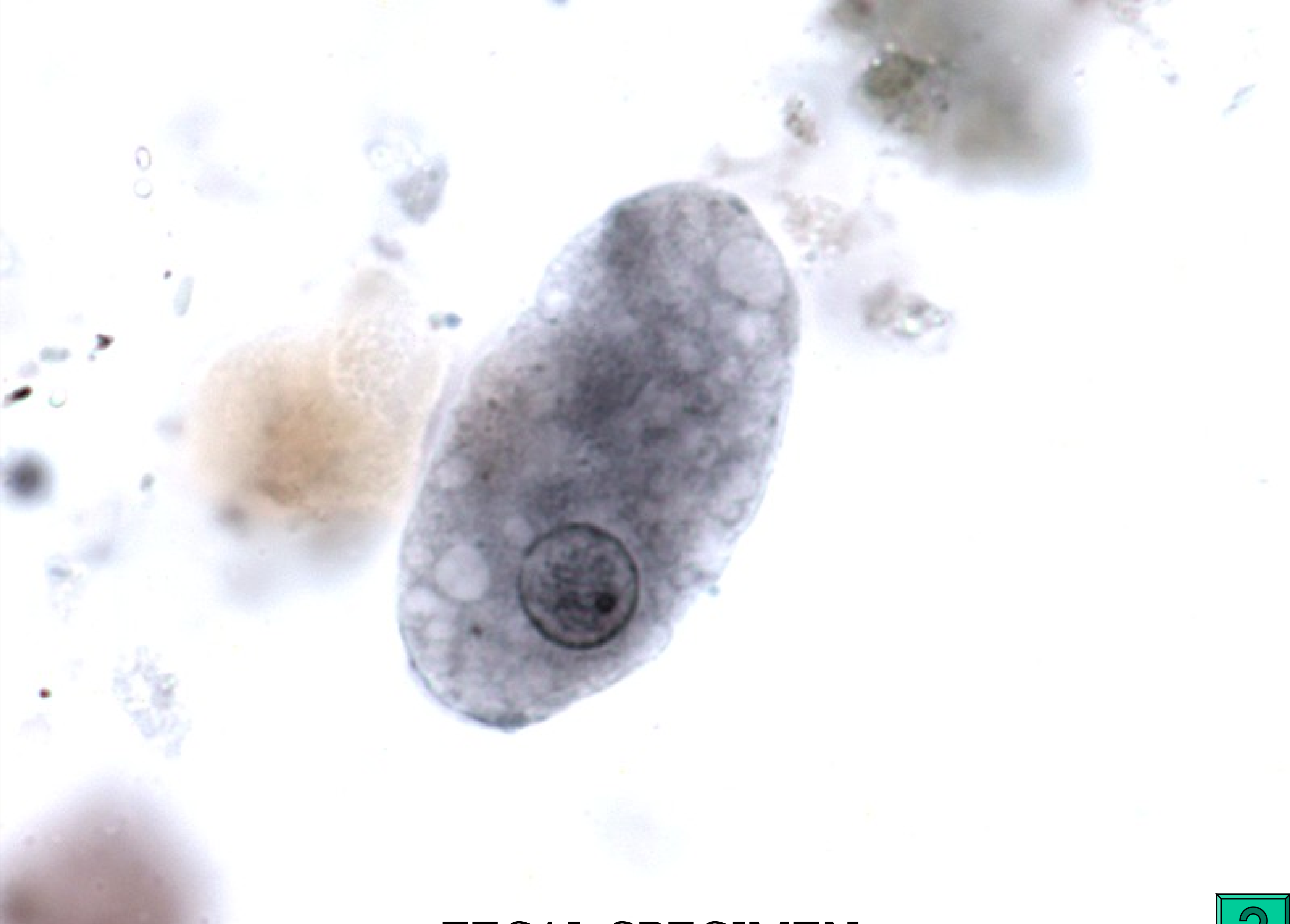
Leishmania donovani amastigotes

- numerous small intracellular parasites in macrophages
- several kinetoplasts visible



Plasmodium malariae erythrocytic schizont

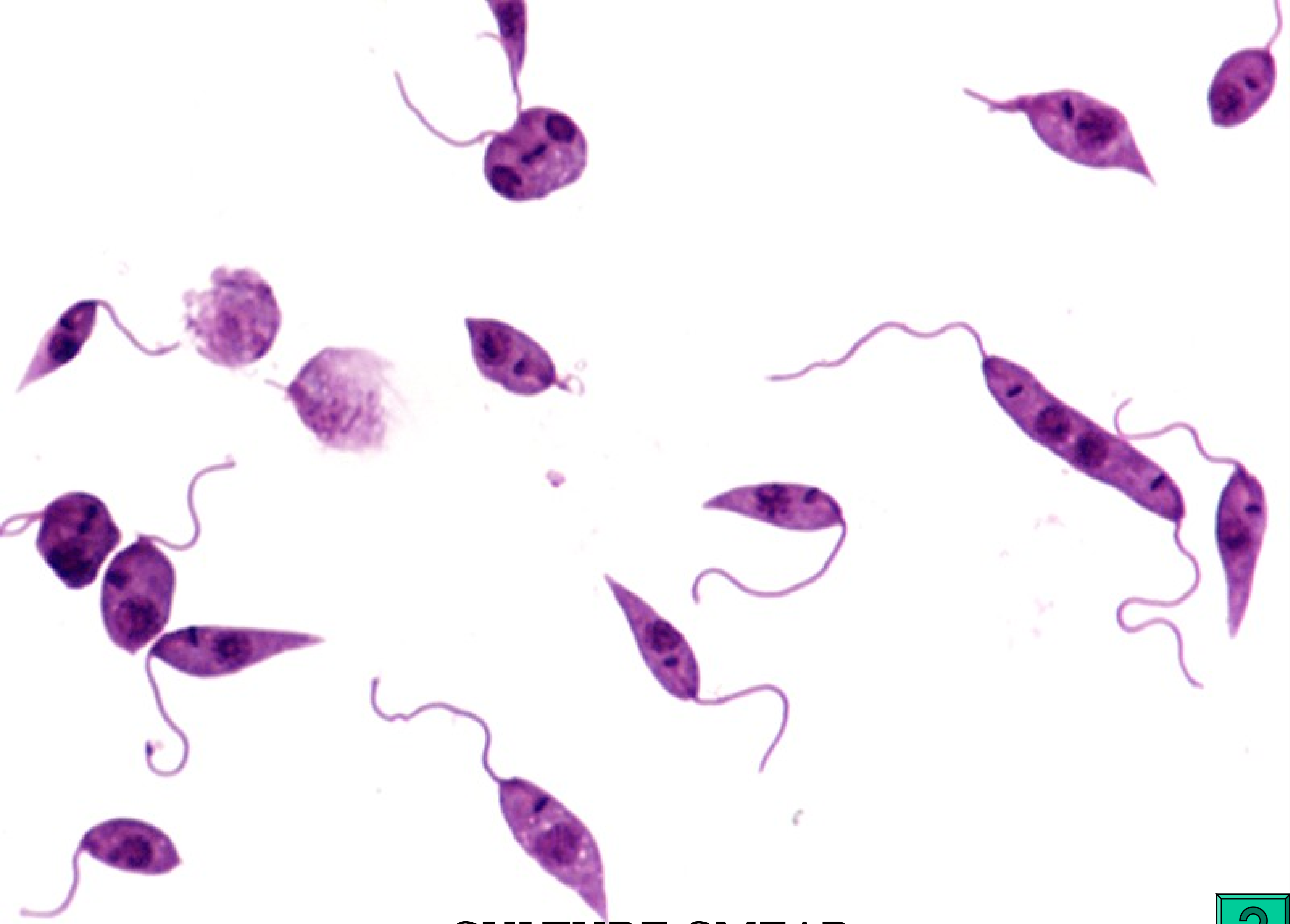
- merozoites arranged in a rosette around periphery
- 8 merozoites/schizont
- prominent hemozoin granules in center
- RBC not enlarged



FECAL SPECIMEN

Entamoeba coli trophozoite

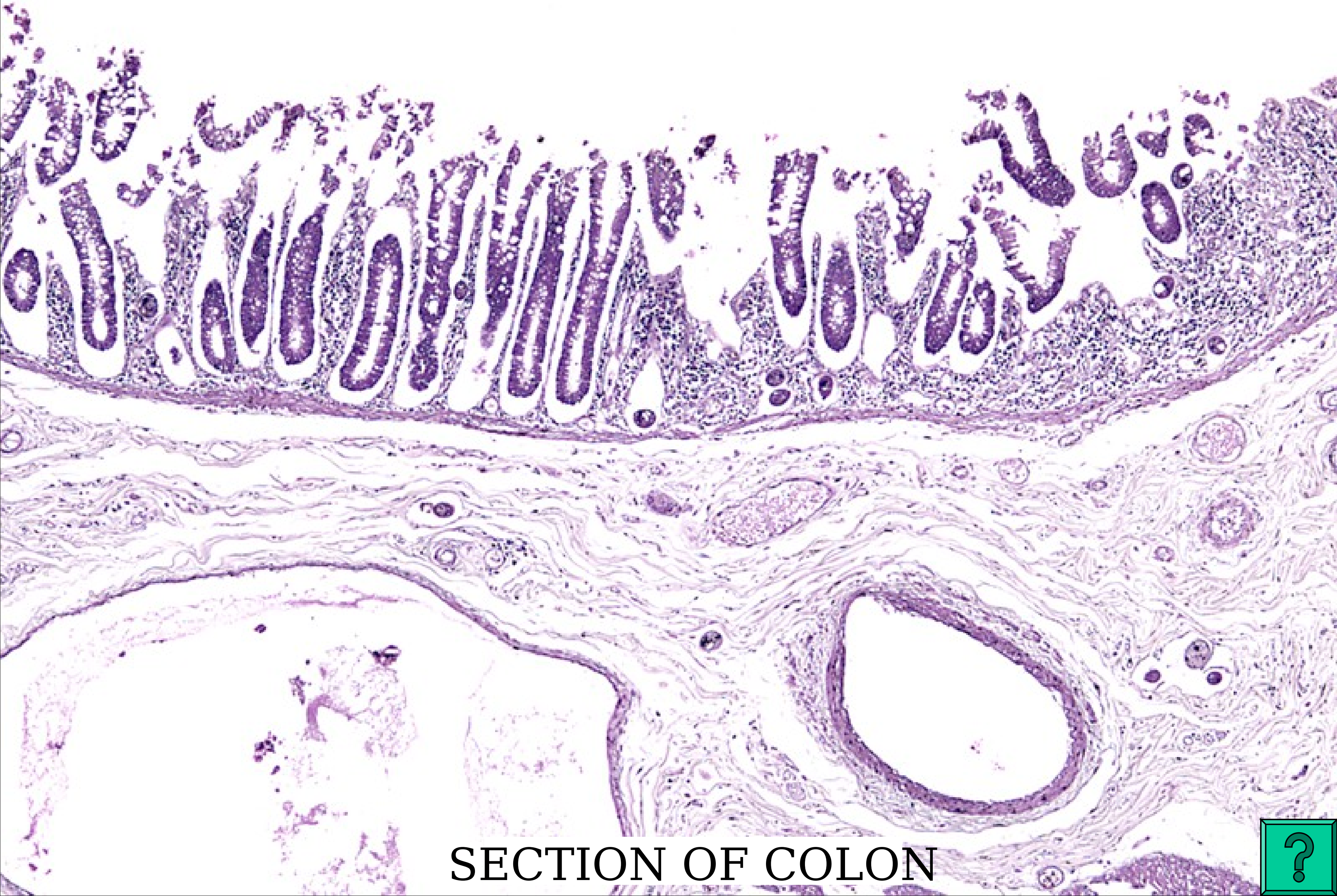
- irregular shape
- cytoplasm containing numerous phagocytosed bacteria
- eccentric nuclear endosome
- coarse peripheral chromatin granules



CULTURE SMEAR

Leishmania sp. promastigotes

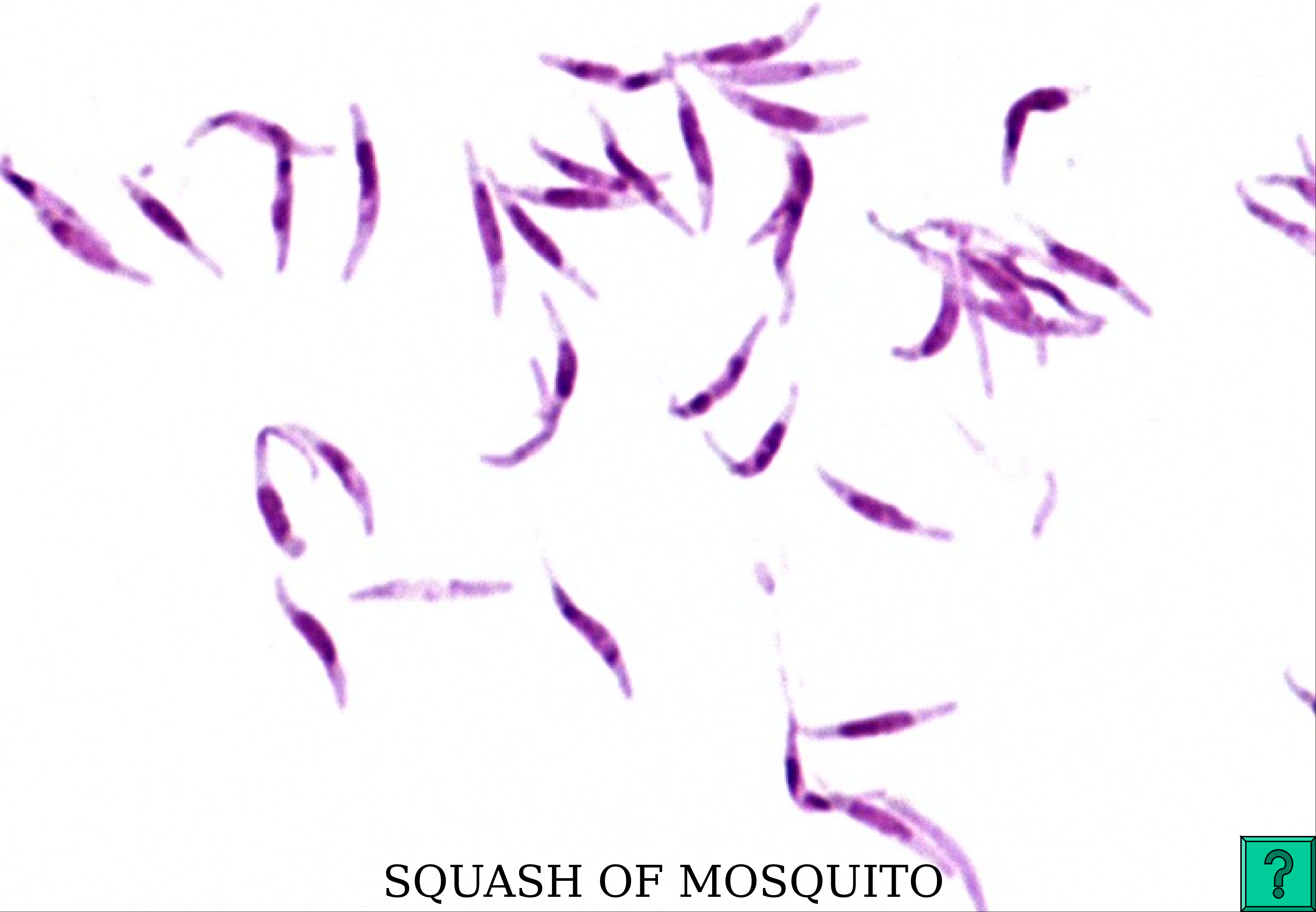
- no undulating membrane
- kinetoplast anterior to nucleus
- free flagellum



SECTION OF COLON

Balantidium coli trophozoites

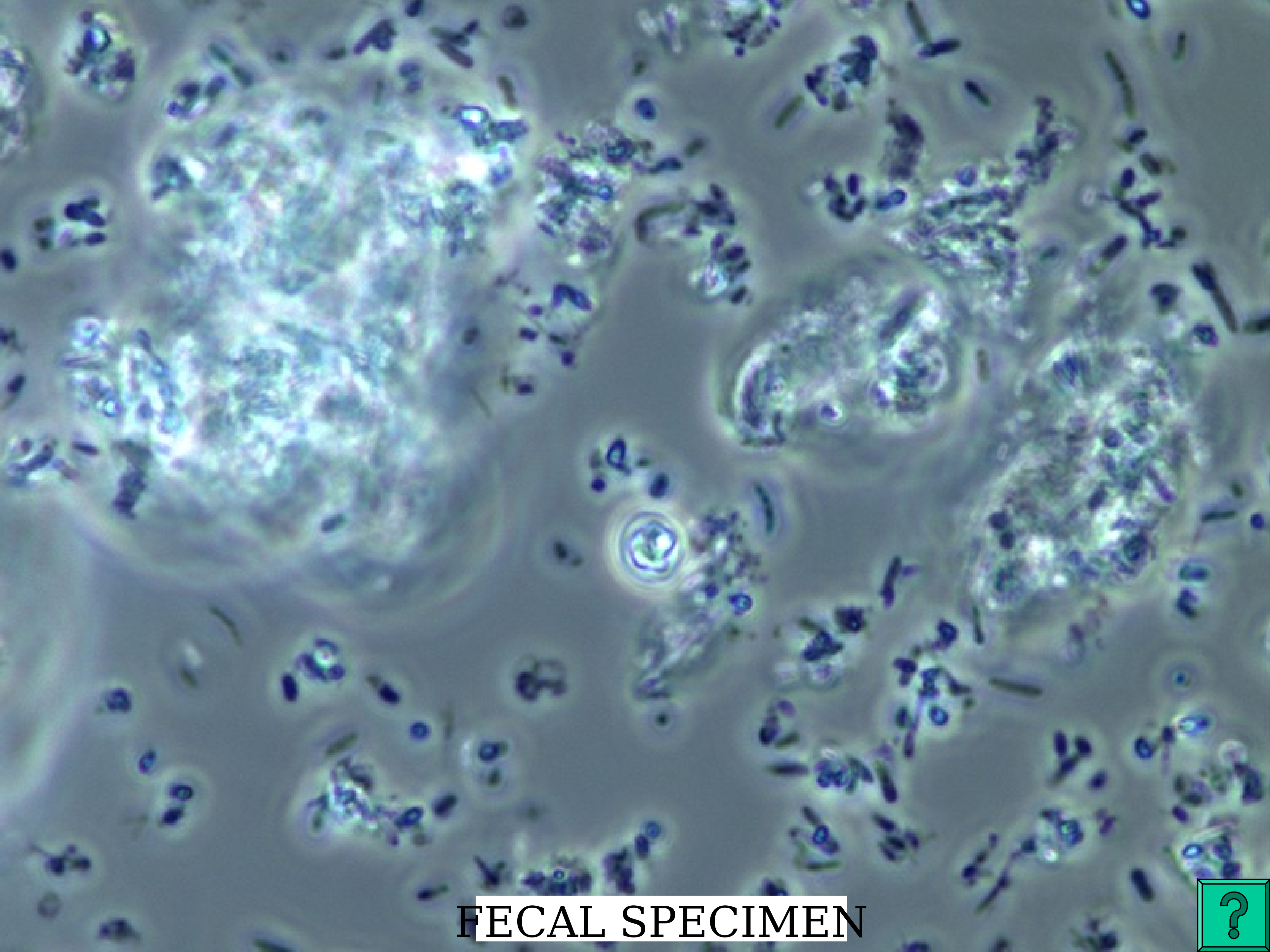
- ulcer in mucosa
- large oval trophozoites visible at base of ulcer and in submucosa



SQUASH OF MOSQUITO

Plasmodium sp. sporozoites

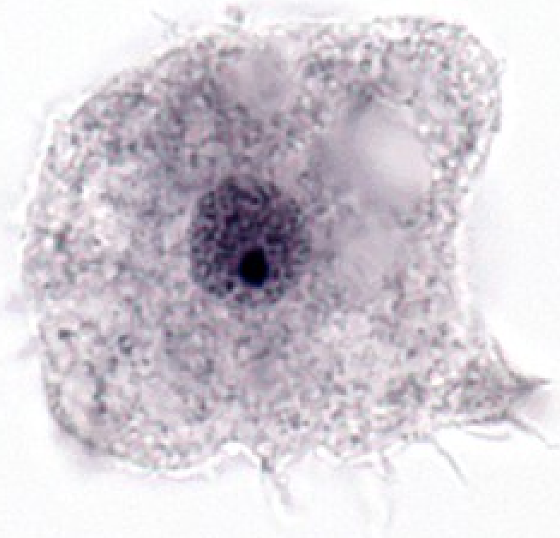
- small
- long, slender
- central nucleus



FECAL SPECIMEN

Cryptosporidium parvum oocyst

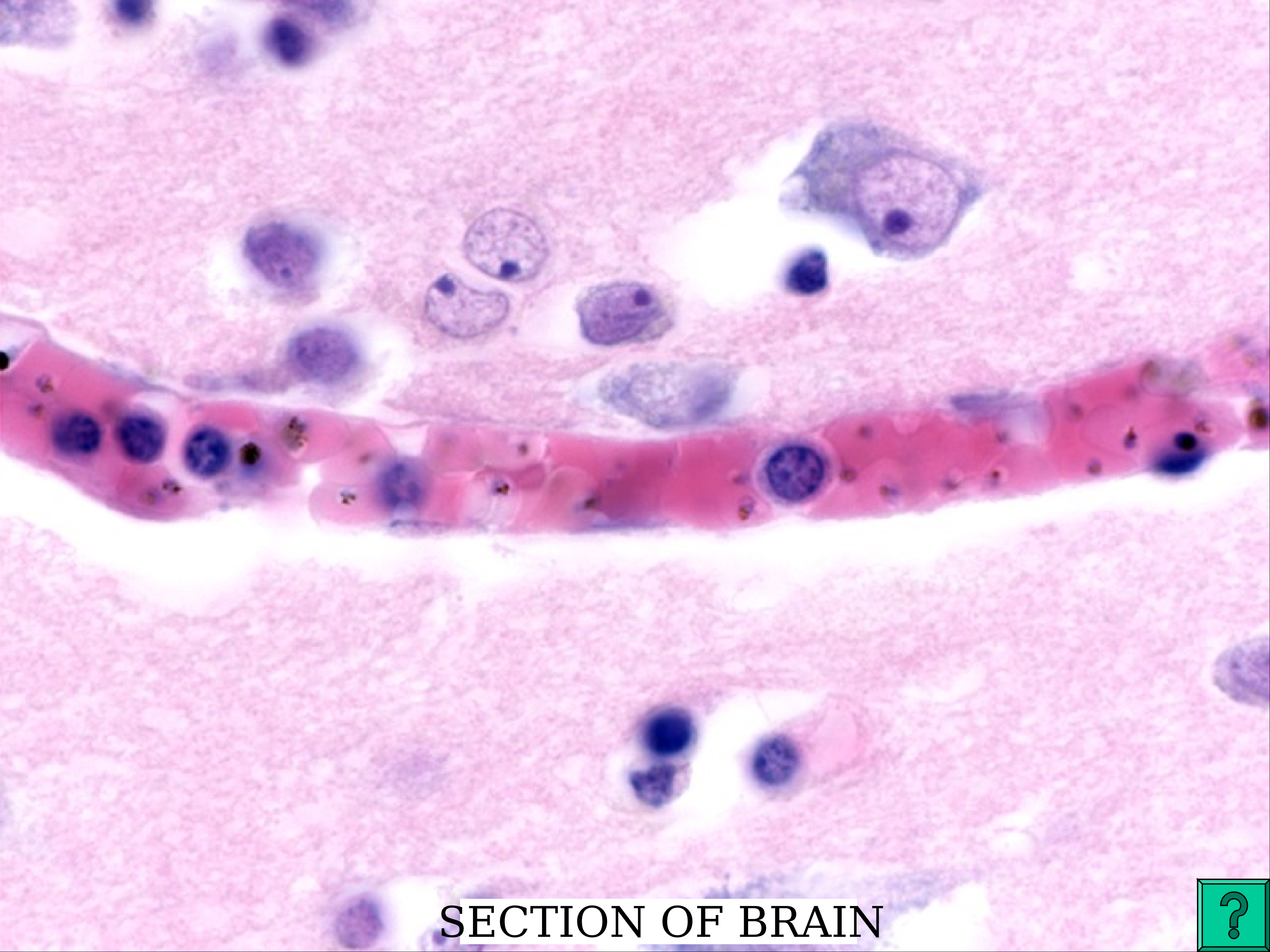
- small (compare to bacteria)
- spherical
- thin wall
- 4 sporozoites



SMEAR OF TISSUE ABCESS

Acanthamoeba sp. trophozoite

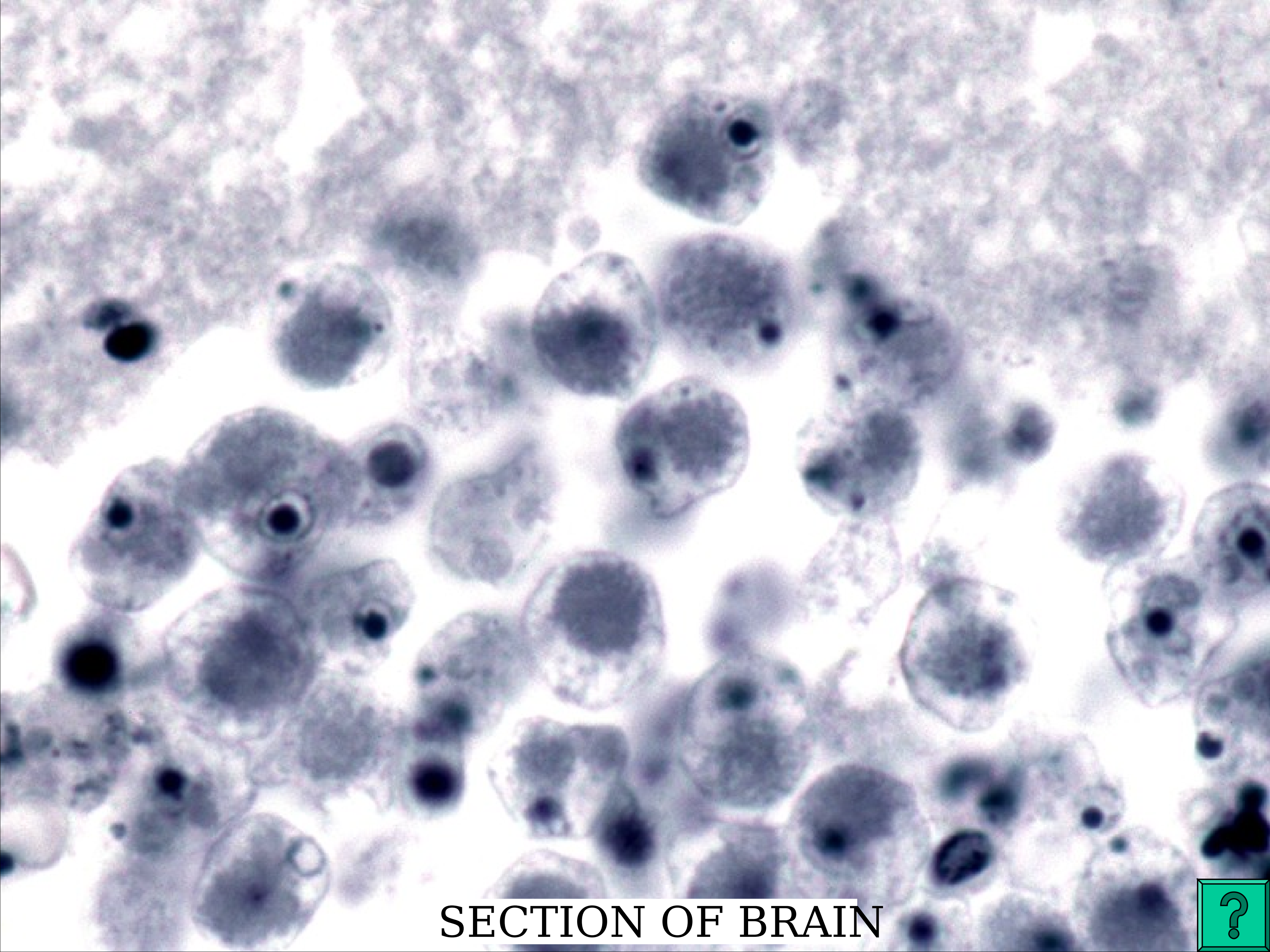
- irregular shape
- branched pseudopodia (rhizopodia)
- large nuclear endosome



SECTION OF BRAIN

Cerebral malaria due to *Plasmodium falciparum*

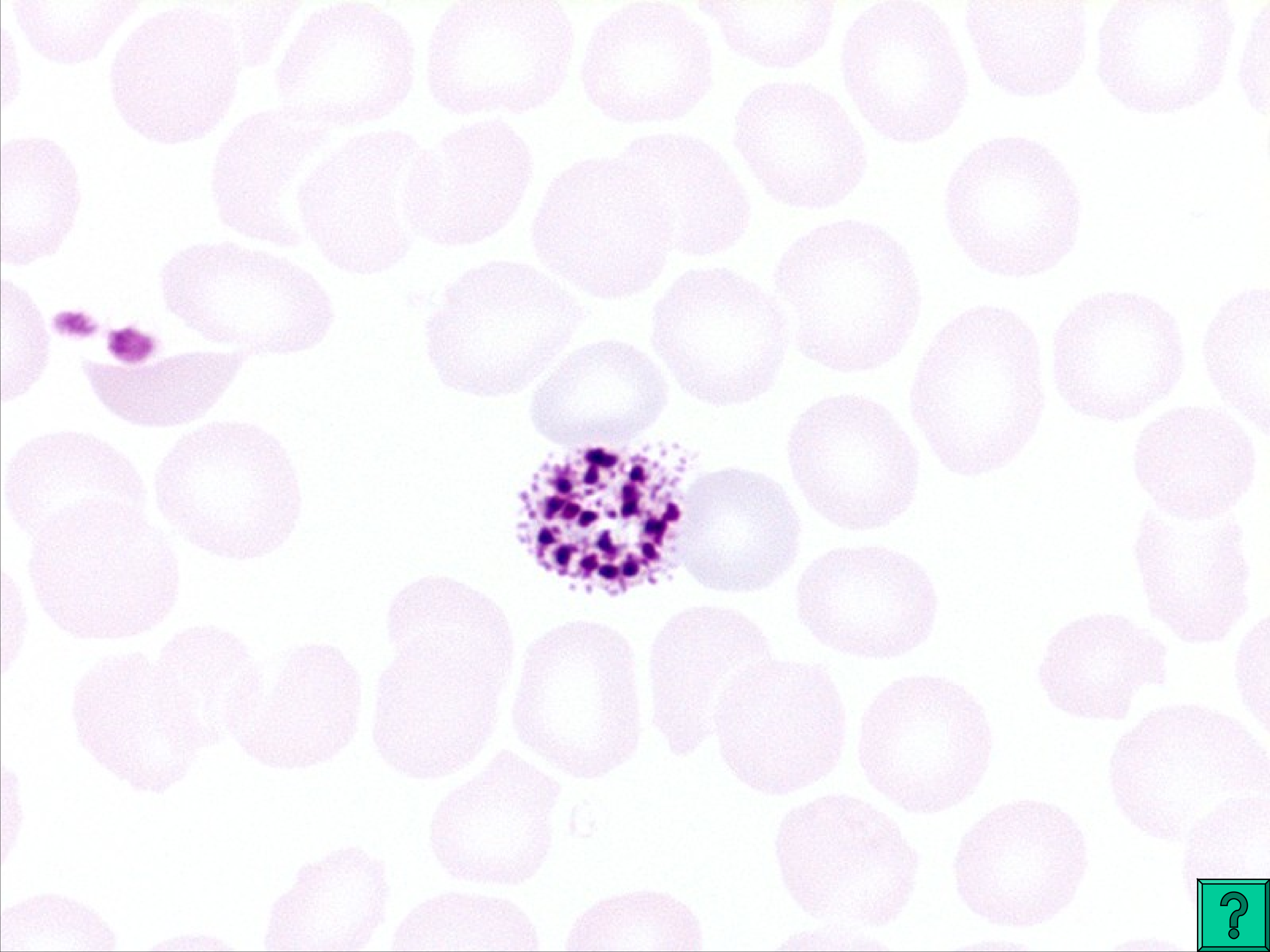
- small blood vessels packed with hemozoin-containing cells



SECTION OF BRAIN

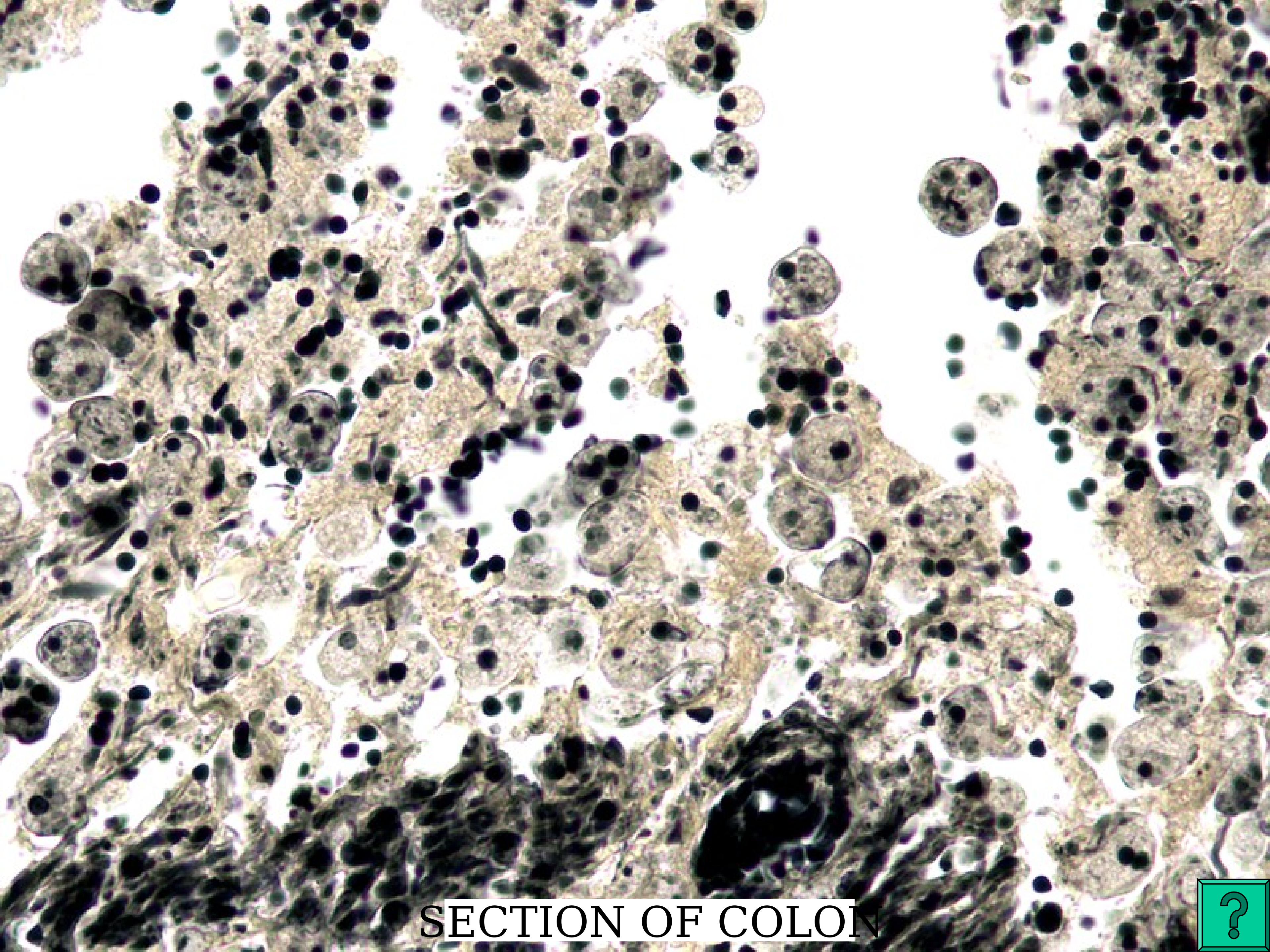
Naegleria fowleri trophozoites (primary amebic meningoencephalitis)

- irregular shape
- large nuclear endosome
- extensive tissue destruction
- absence of cyst forms



Plasmodium vivax erythrocytic schizont

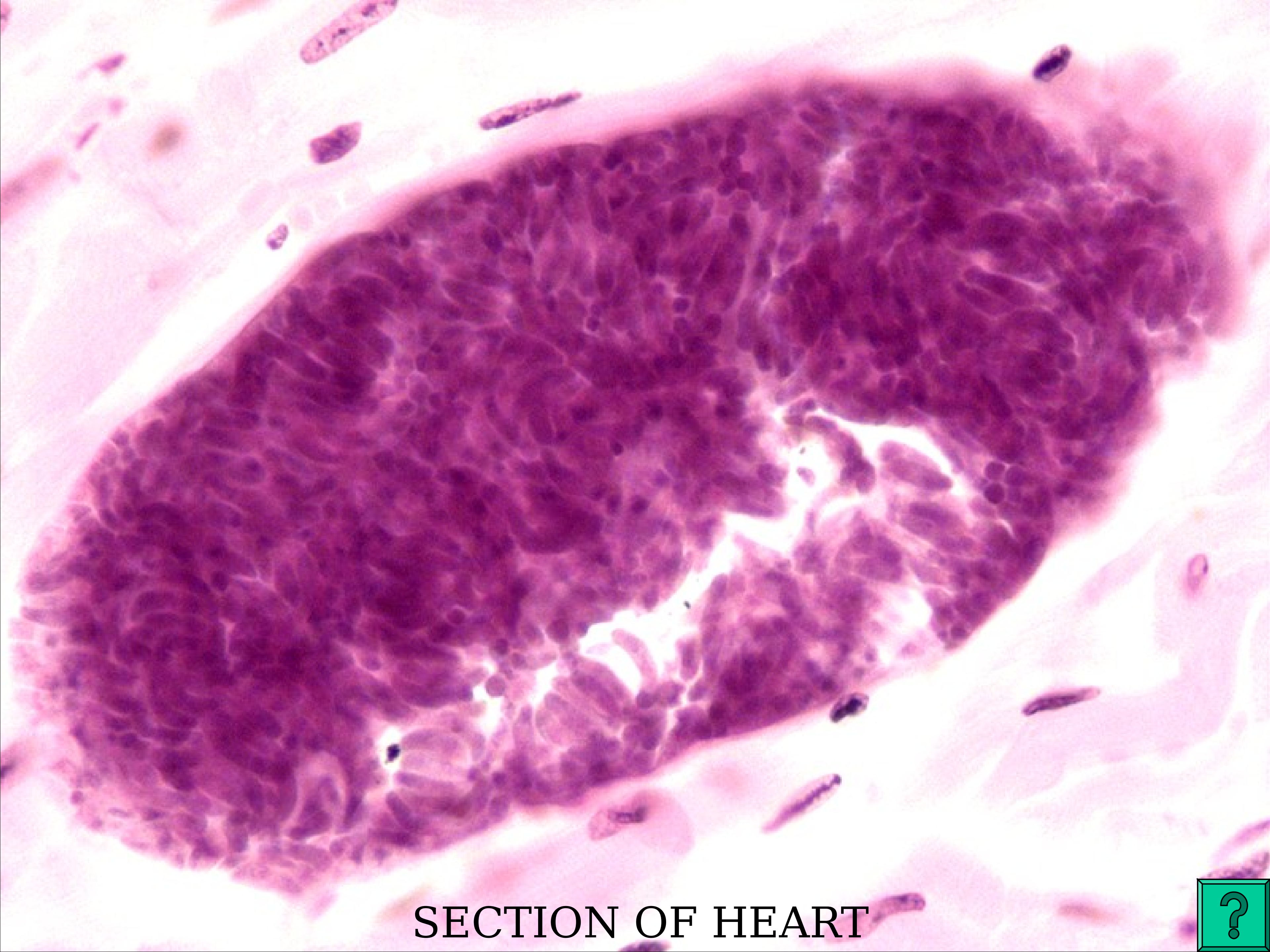
- 18 merozoites (from 12 to 24, average of 16)
- Schüffner's dots
- enlarged, decolorized RBC



SECTION OF COLON

Entamoeba histolytica ulcerative colitis

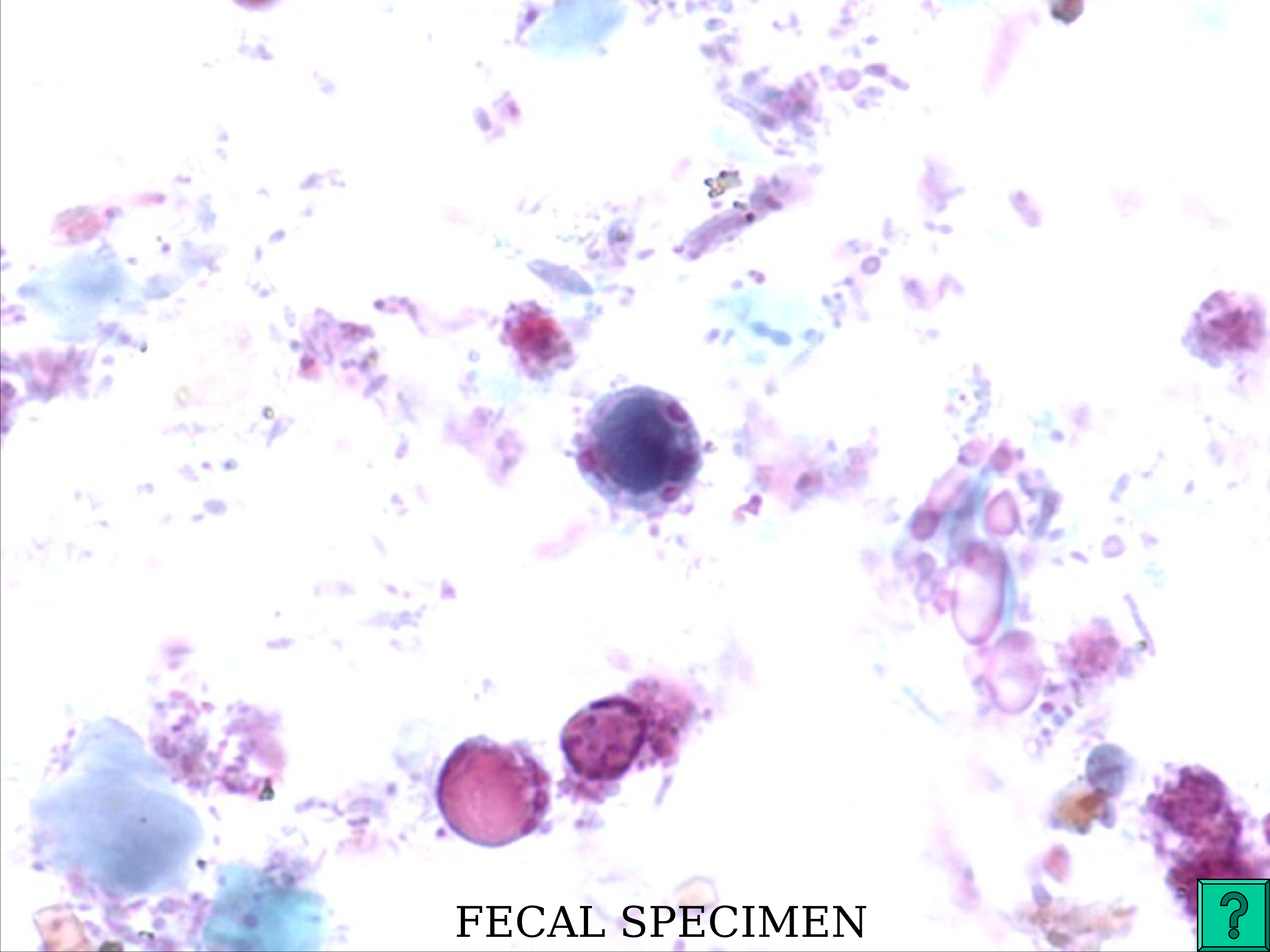
- flask-shaped ulcer in mucosa and submucosa
- ameboid trophozoites with phagocytosed RBCs



SECTION OF HEART

Sarcocystis sp. zoitocyst

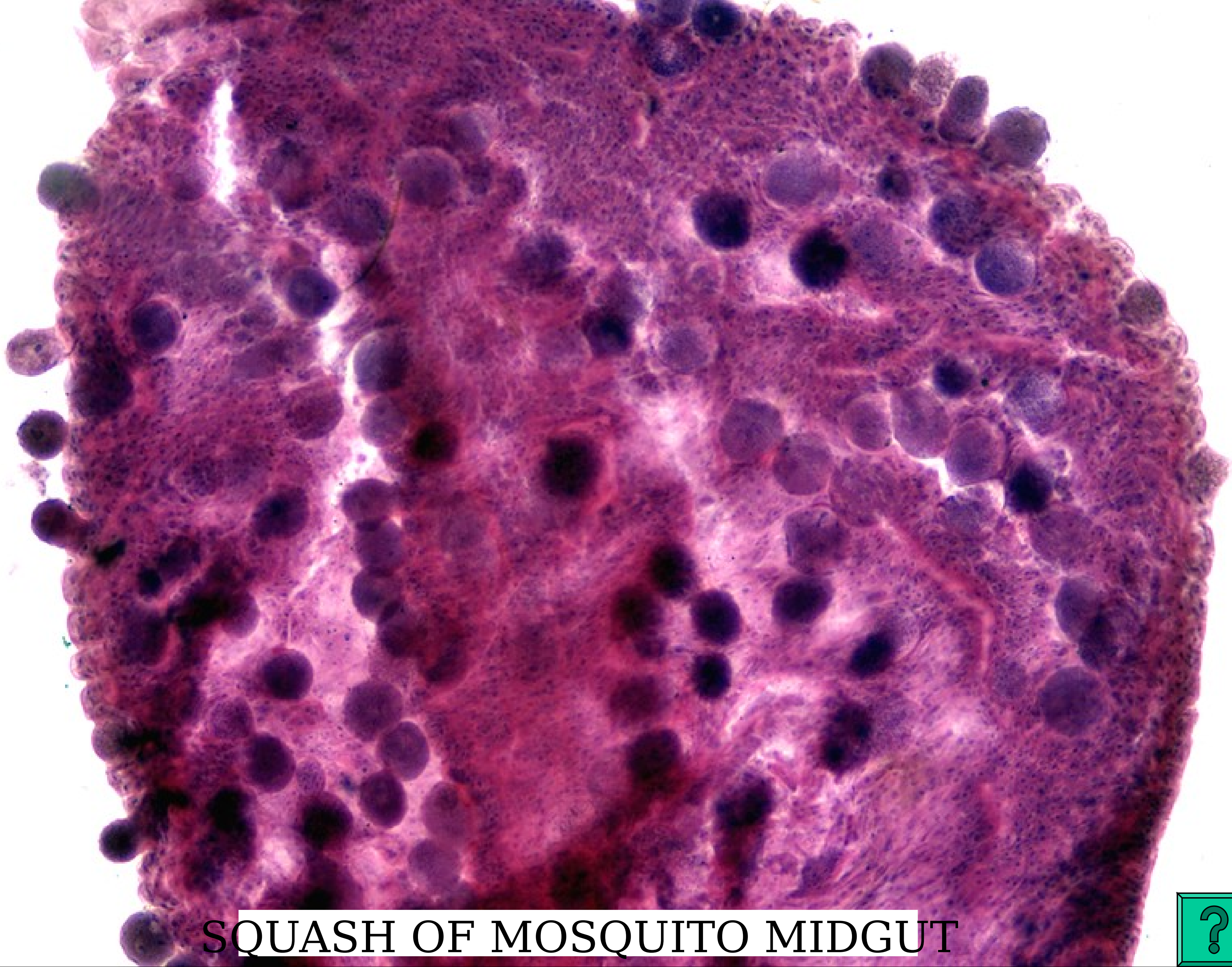
- cyst within cardiac myofiber
- contains merozoites (which are larger than those of *Toxoplasma gondii*)



FECAL SPECIMEN

Blastocystis hominis cysts

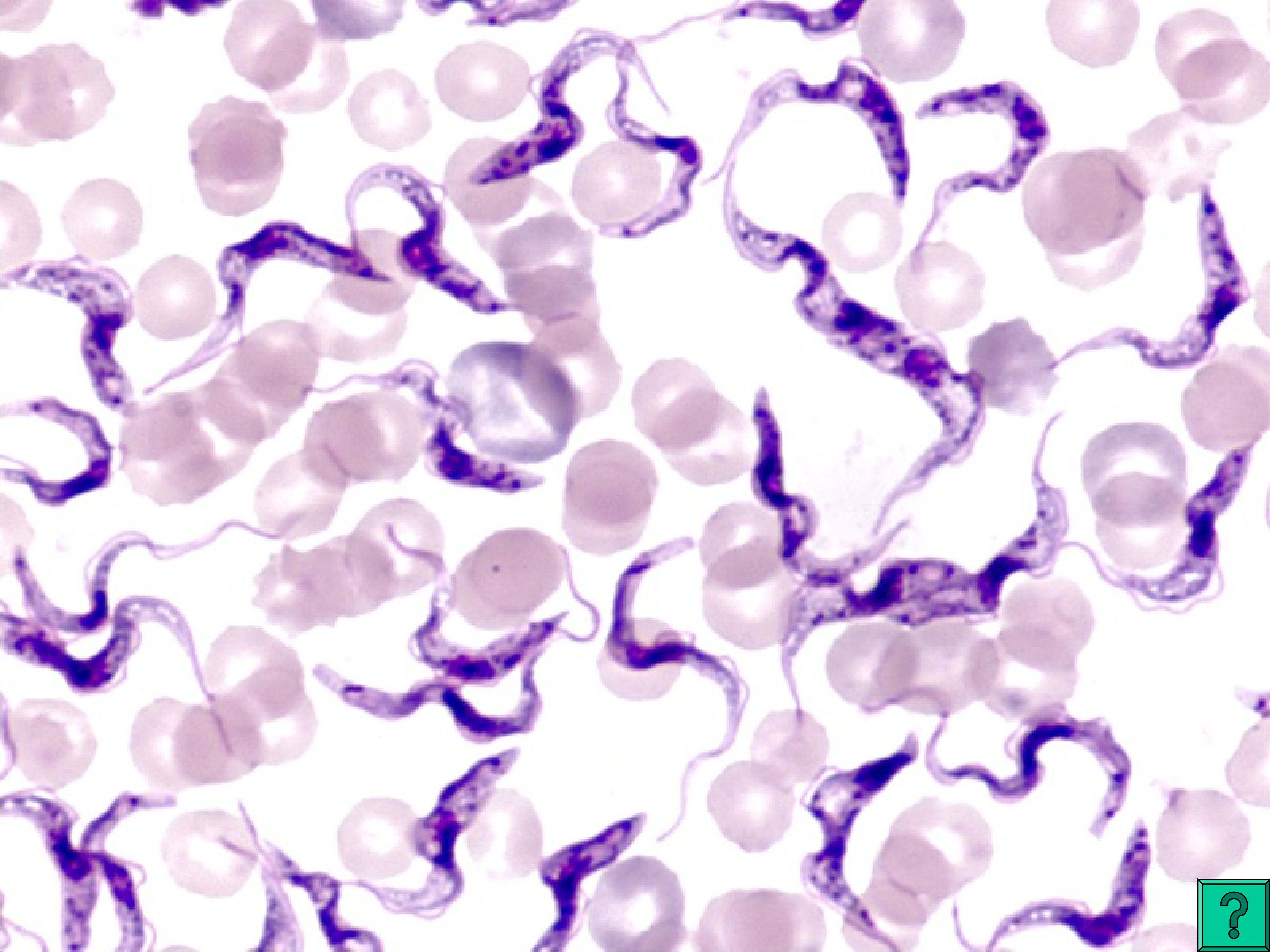
- round to oval refractile body
- central inclusion
- peripheral cytoplasm
- peripheral granules



SQUASH OF MOSQUITO MIDGUT

Plasmodium sp. oocysts

- spherical bodies bulging into hemocoel
- contain many nuclei (developing sporozoites)



Trypanosoma brucei rhodesiense or *T. b. gambiense* trypomastigotes

- high parasitemia
- undulating membrane
- free flagellum
- small kinetoplast, posterior to nucleus
- elongate “S” when fixed
- dividing forms present
- volutin granules present in cytoplasm

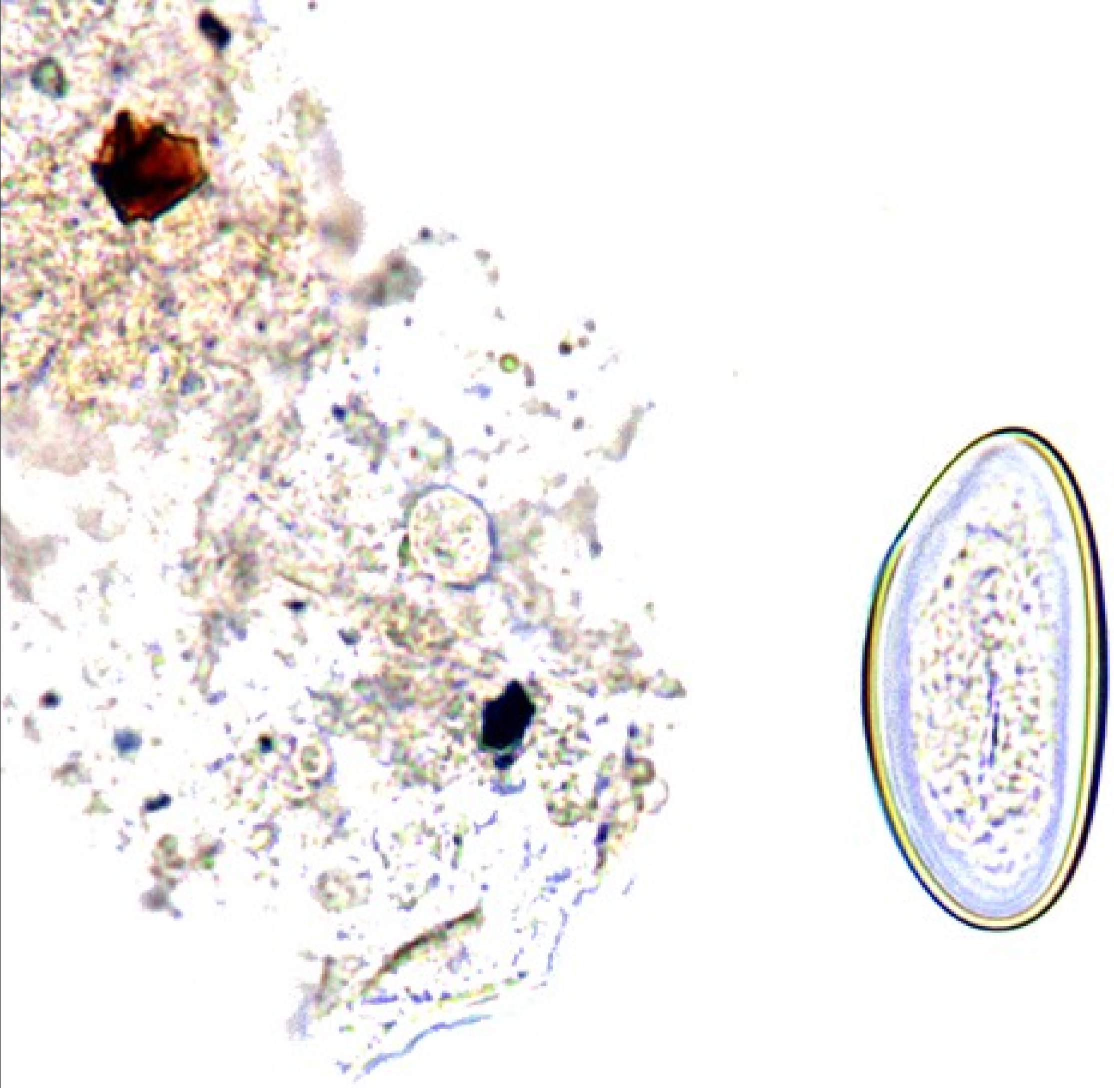
Self Test - Helminths

Start | Start | Start | Start

For each specimen, name the genus, species, and developmental stage. Hypothetical source of the specimen is usually given.

- ? provides the answer along with diagnostic features.
- ↺ returns you to the photograph of the specimen.
- ⏮ returns you to this slide.

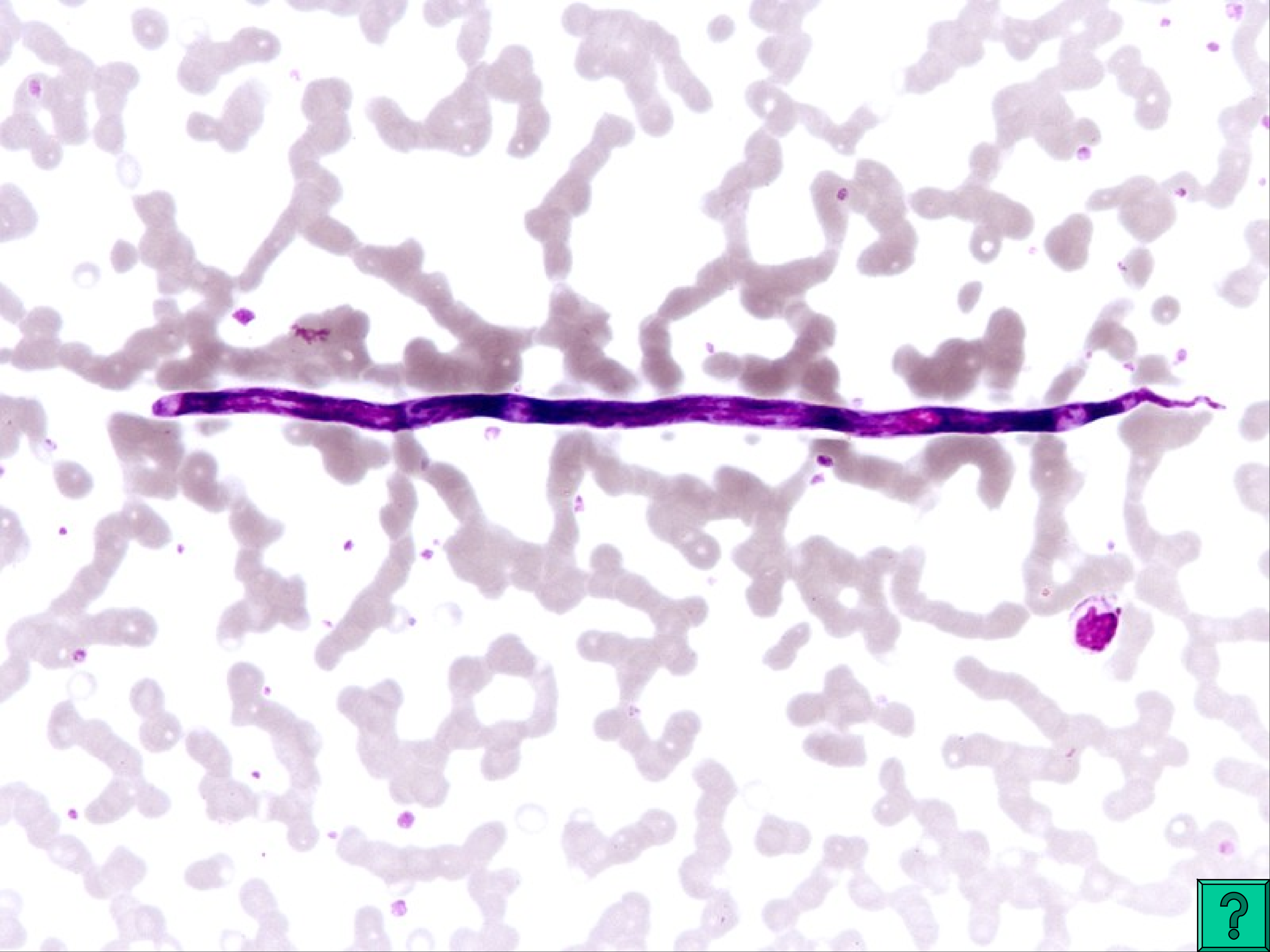
By choosing a different Start button, and then proceeding forward or backward, you can vary the sequence of questions each time you take the test.



FECAL SPECIMEN

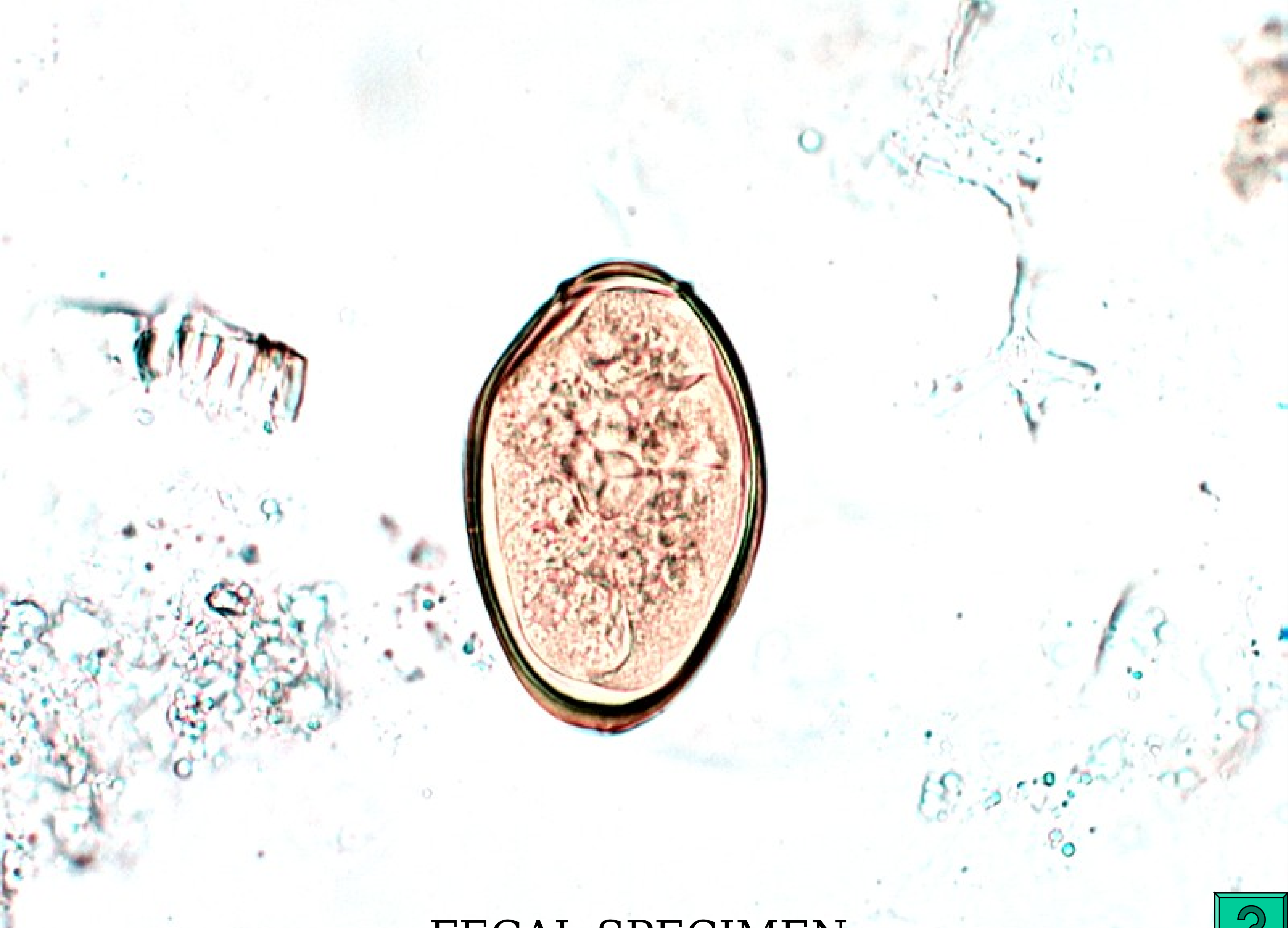
Enterobius vermicularis egg

- hyaline color
- thick shell
- unembryonated or with larval nematode
- flat on one side
- usually recovered from perianal skin, but will occur in feces



Loa loa microfilaria

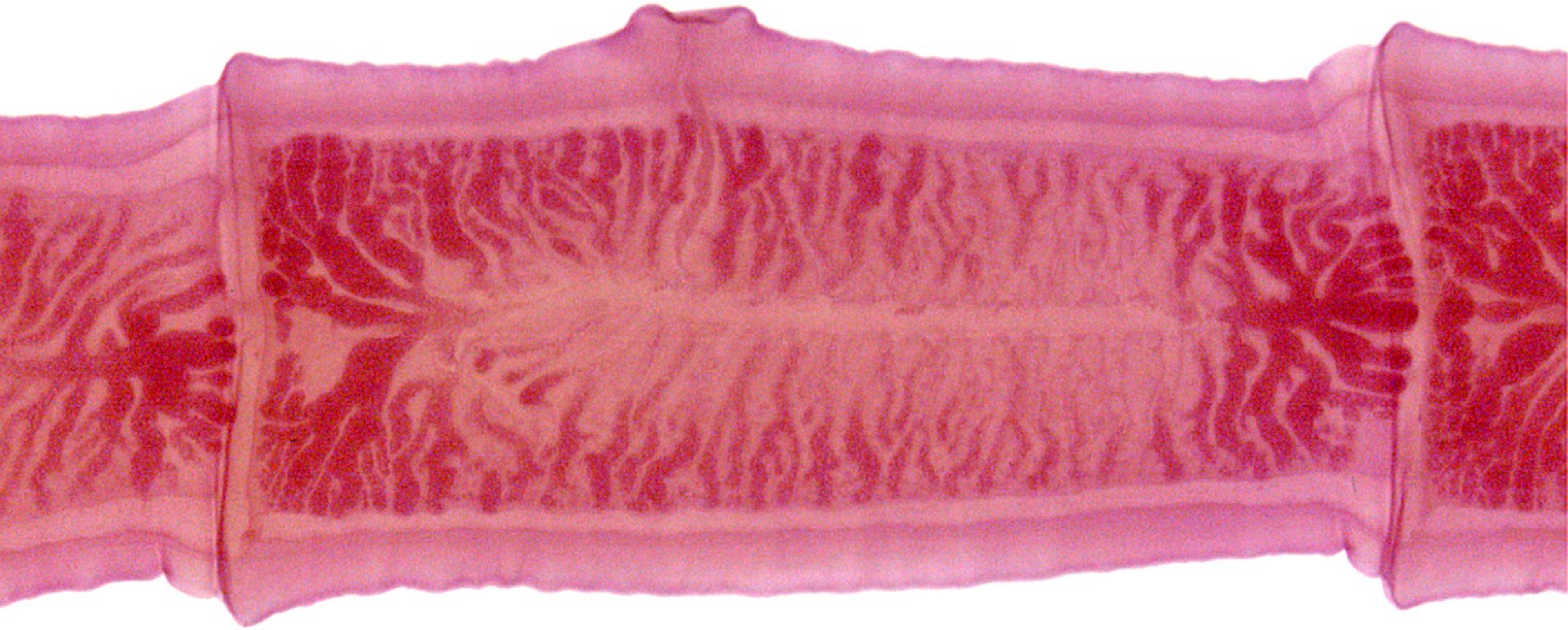
- unstained sheath
- nuclei in tail
- solid column of nuclei
- small cephalic space



FECAL SPECIMEN

Paragonimus westermani egg

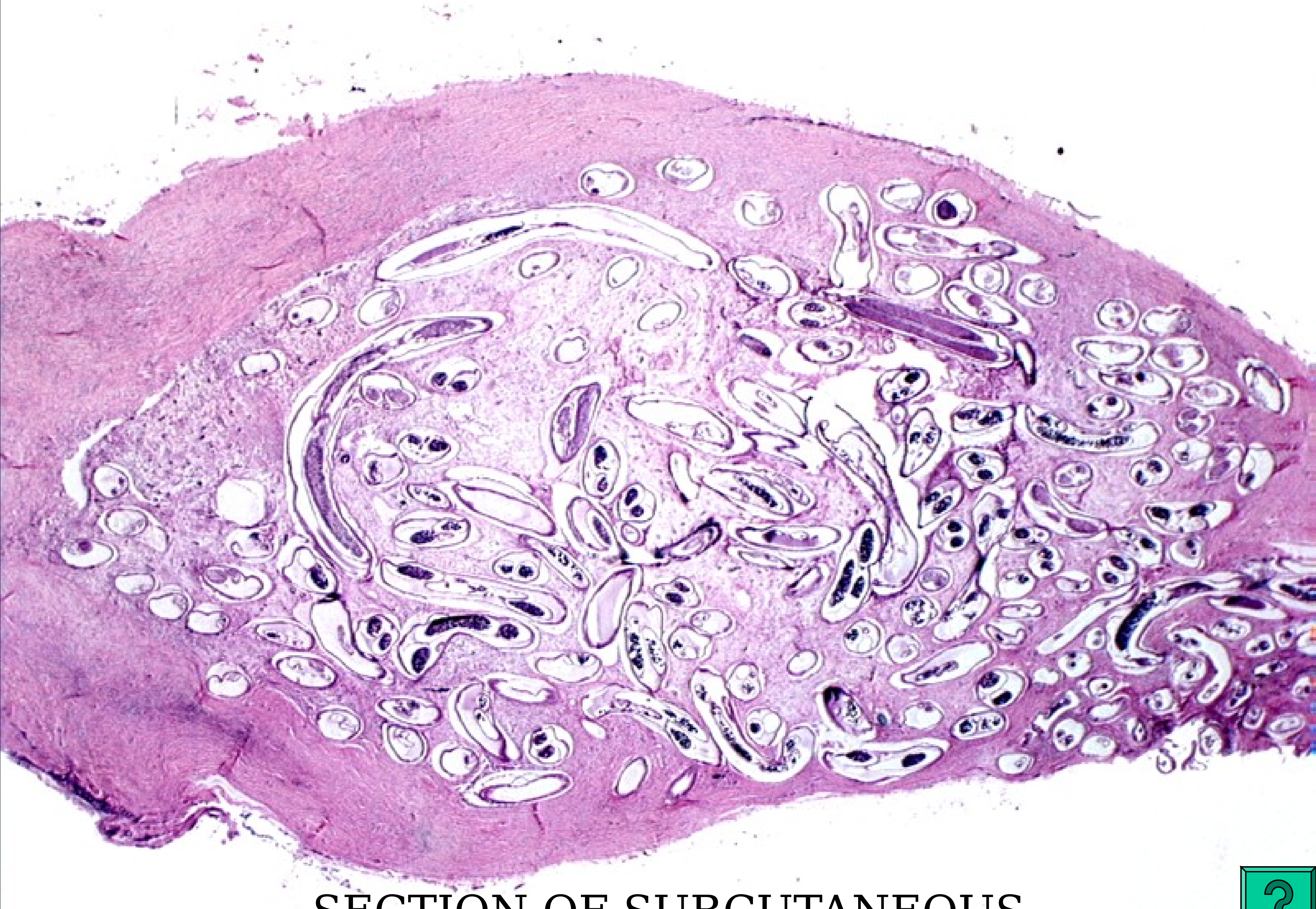
- medium to large egg
- oval
- golden brown
- unembryonated
- operculate
- abopercular thickening



FECAL SPECIMEN

Taenia saginata gravid proglottid

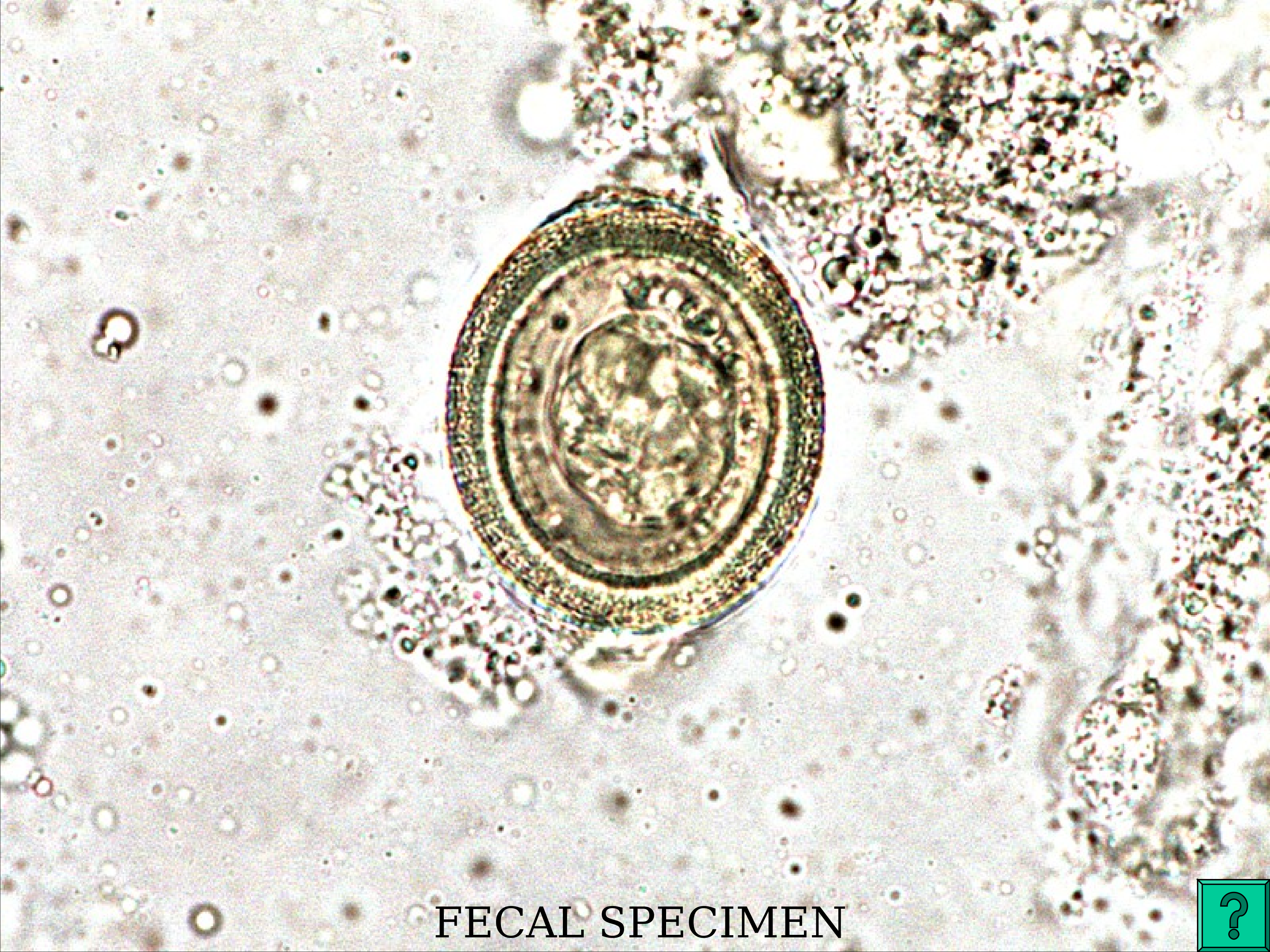
- elongate
- > 14 side branches of uterus
- single lateral genital pore



SECTION OF SUBCUTANEOUS

Onchocerca volvulus in nodule

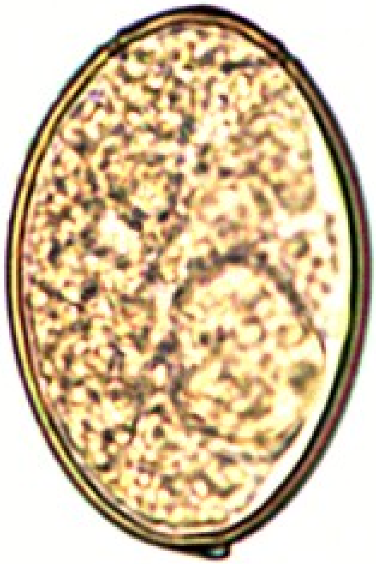
- coiled thread-like worms
- fibrous connective tissue surrounding worms



FECAL SPECIMEN

Taeniid egg

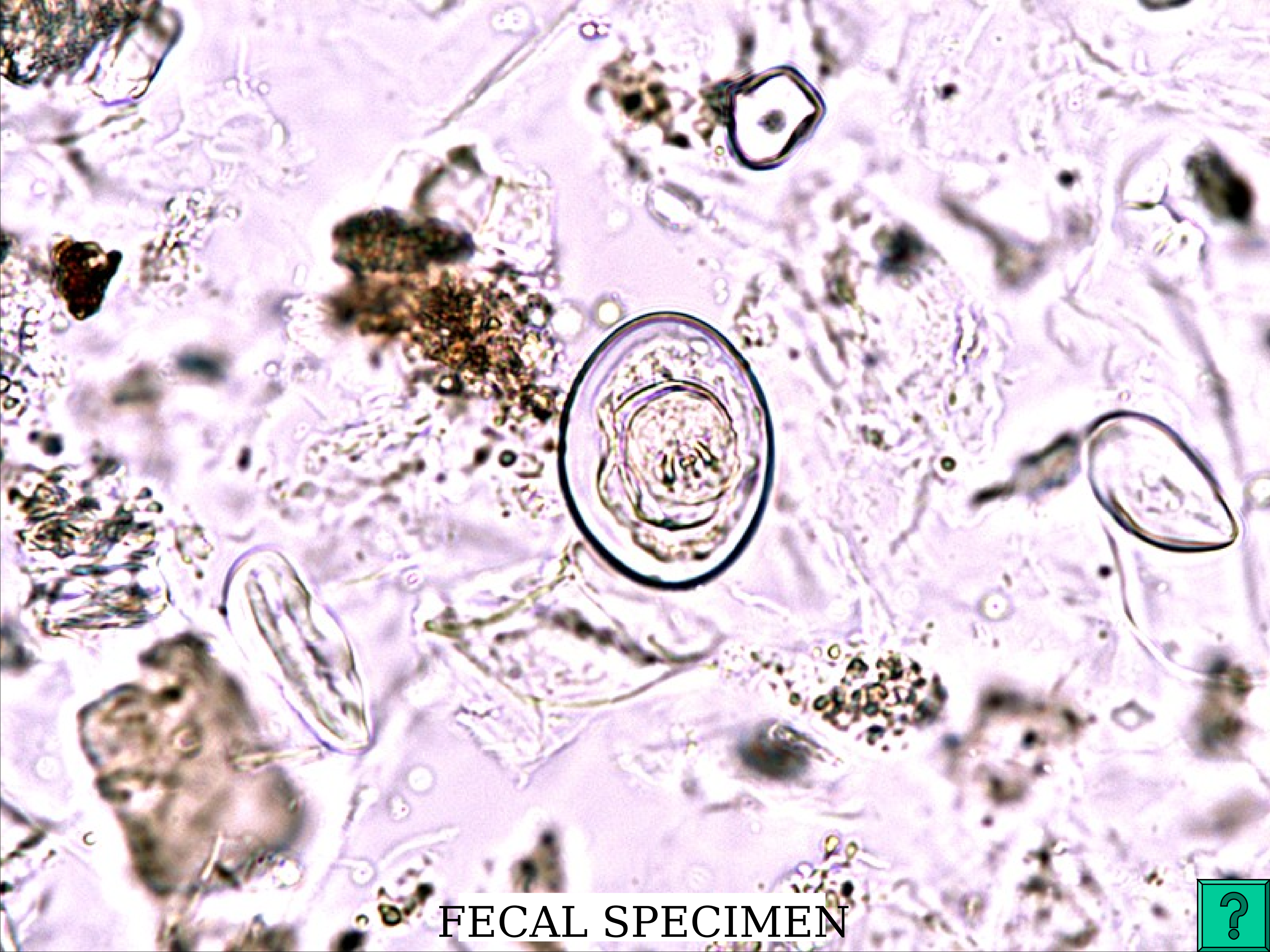
- small to medium size
- oval to round shape
- brown color
- oncosphere within 2-layered embryophore
- outer embryophore layer with striations
- gelatinous layer and outer capsule often lost
- non operculate



FECAL SPECIMEN

Diphyllobothrium latum egg

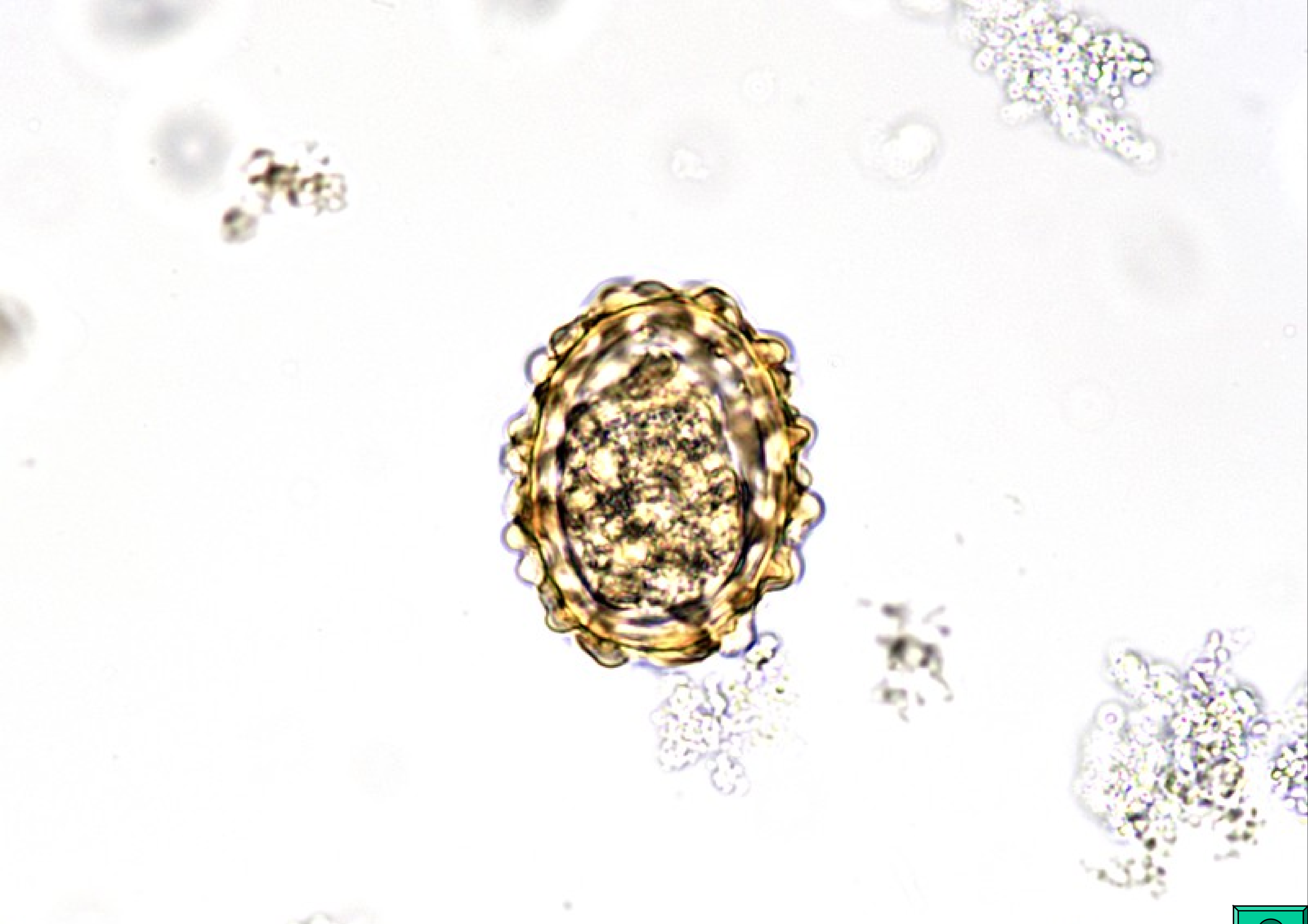
- medium sized
- ovoid
- light yellow color
- unembryonated
- operculate
- abopercular process



FECAL SPECIMEN

Hymenolepis nana egg

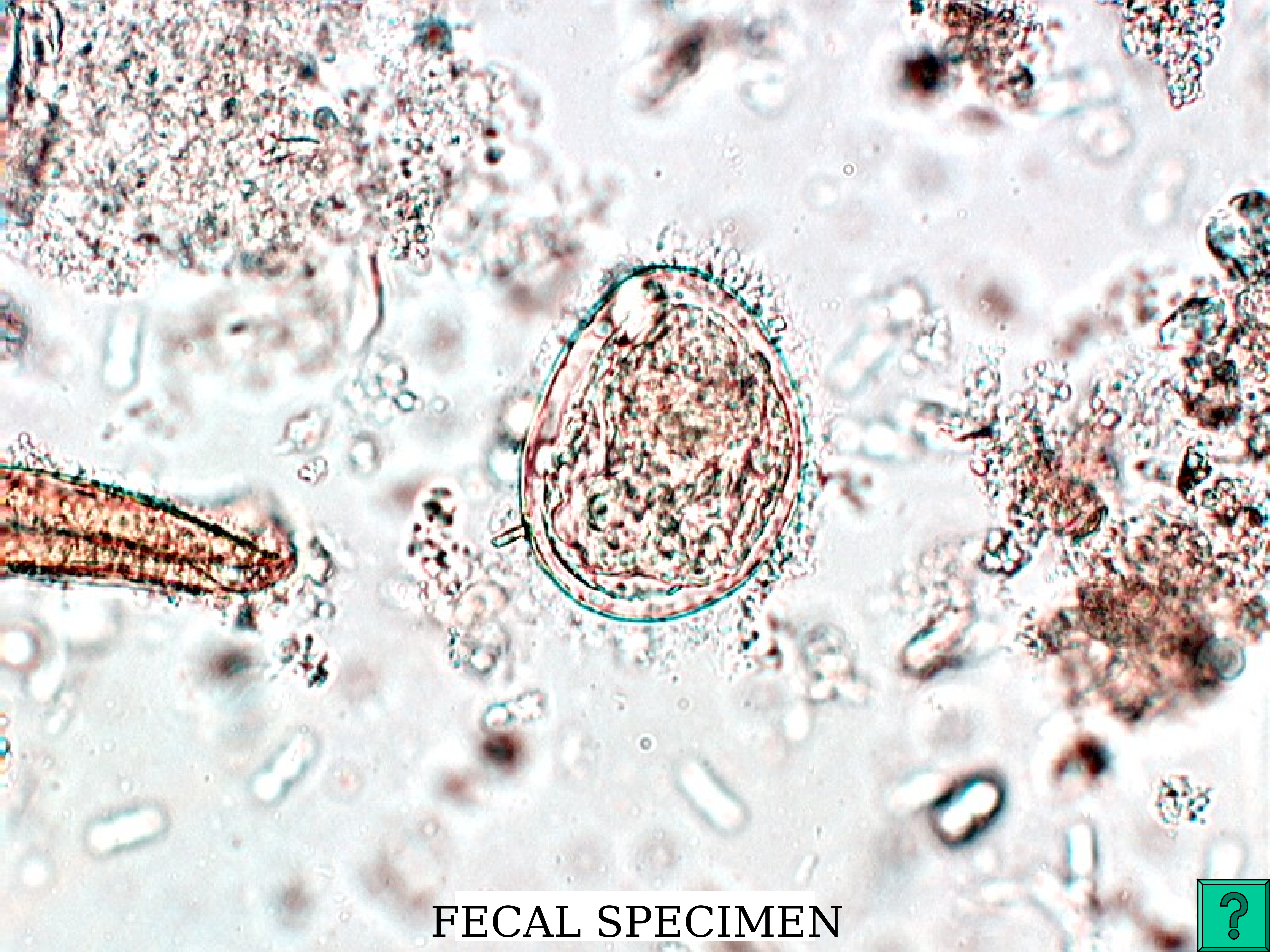
- medium size
- round to oval
- hyaline color
- contains oncosphere within embryophore
- embryophore with polar filaments
- gelatinous granular layer around embryophore
- outer capsule
- non operculate



FECAL SPECIMEN

Ascaris lumbricoides egg

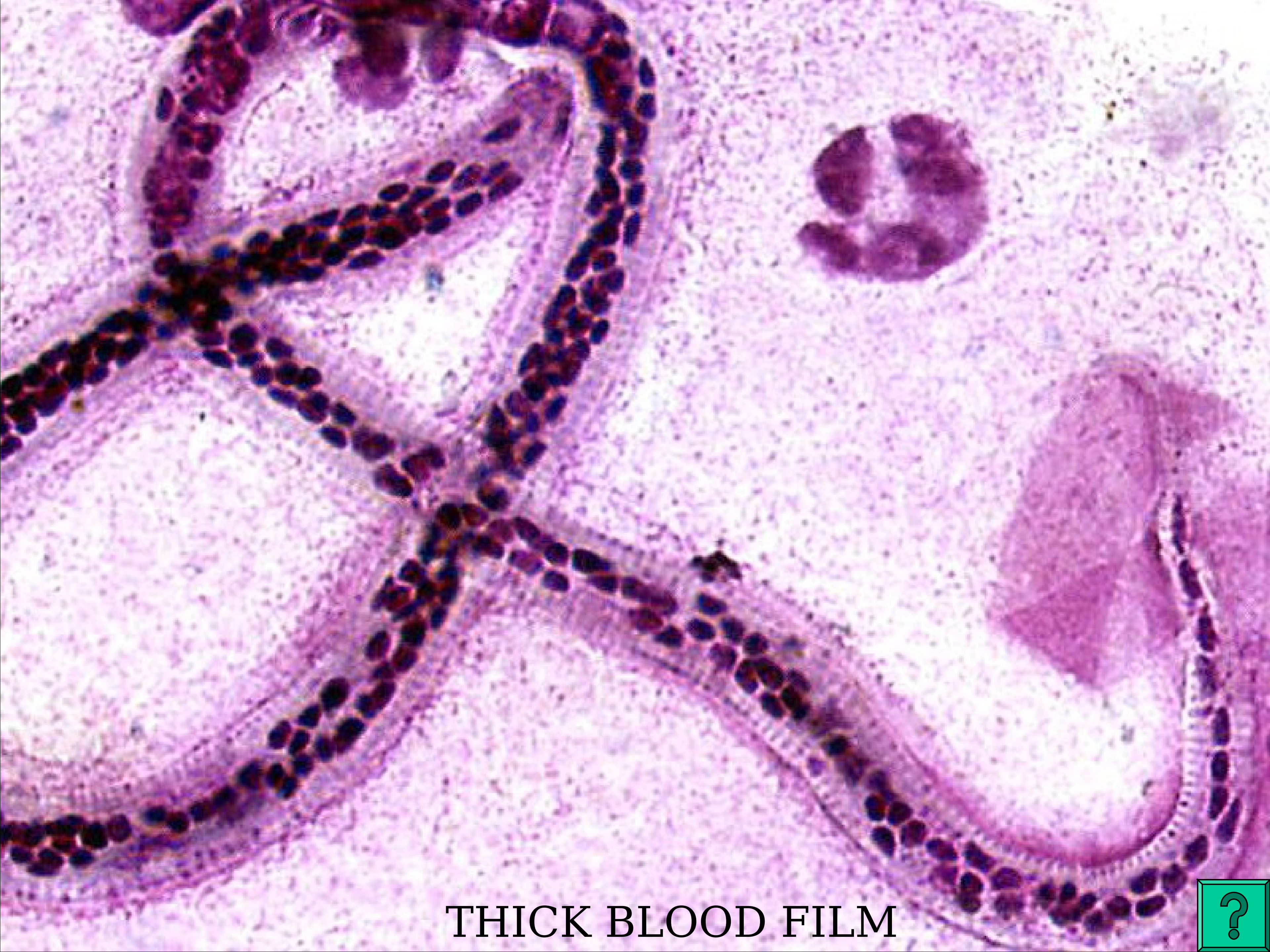
- medium size
- oval
- brown color
- mammillated surface
- unembryonated
- non operculate



FECAL SPECIMEN

Schistosoma japonicum egg

- medium size
- oval to round
- hyaline to yellow brown color
- thin shell
- non operculate
- contains miracidium
- small lateral spine
- often with adhering fecal debris



THICK BLOOD FILM

Microfilaria of *Wucheraria bancrofti*

- sheathed
- short cephalic space
- dispersed column of nuclei
- no nuclei in tail

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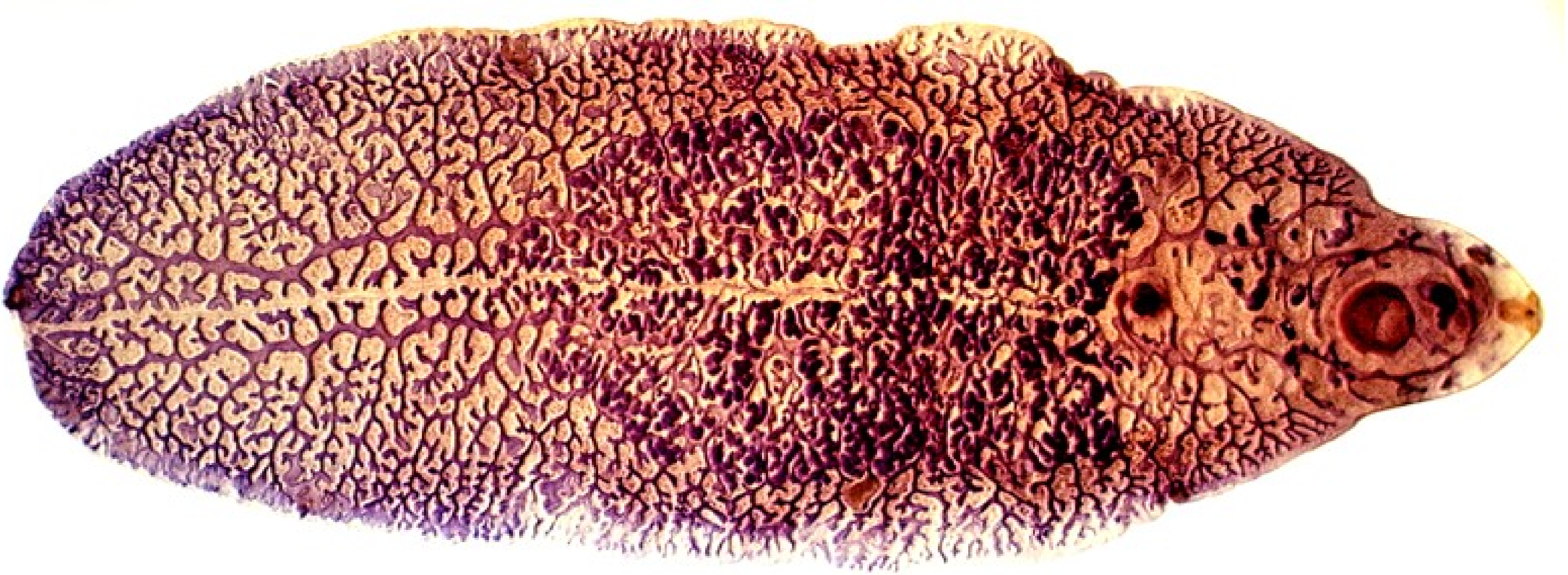

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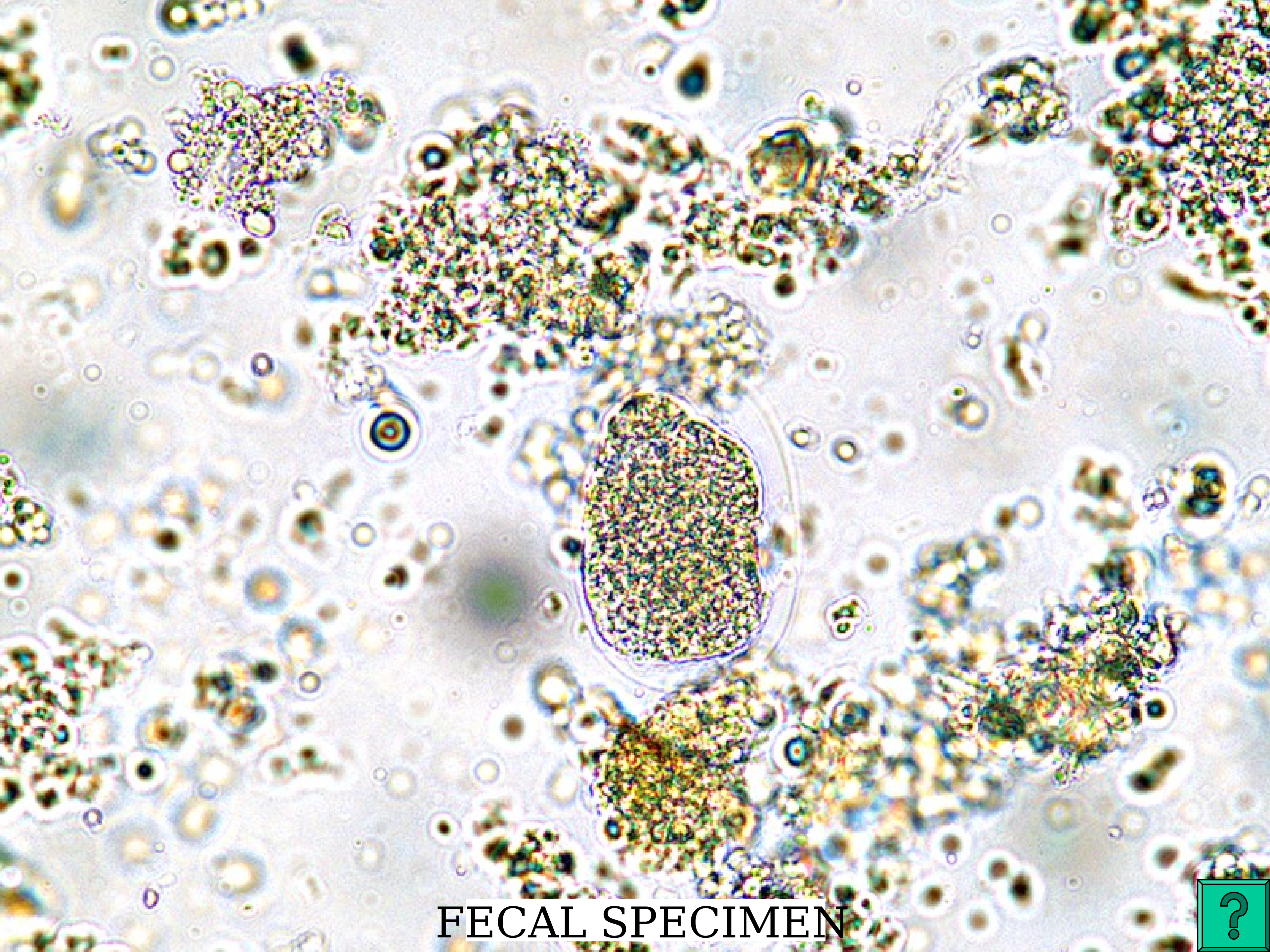
Fasciola hepatica adult

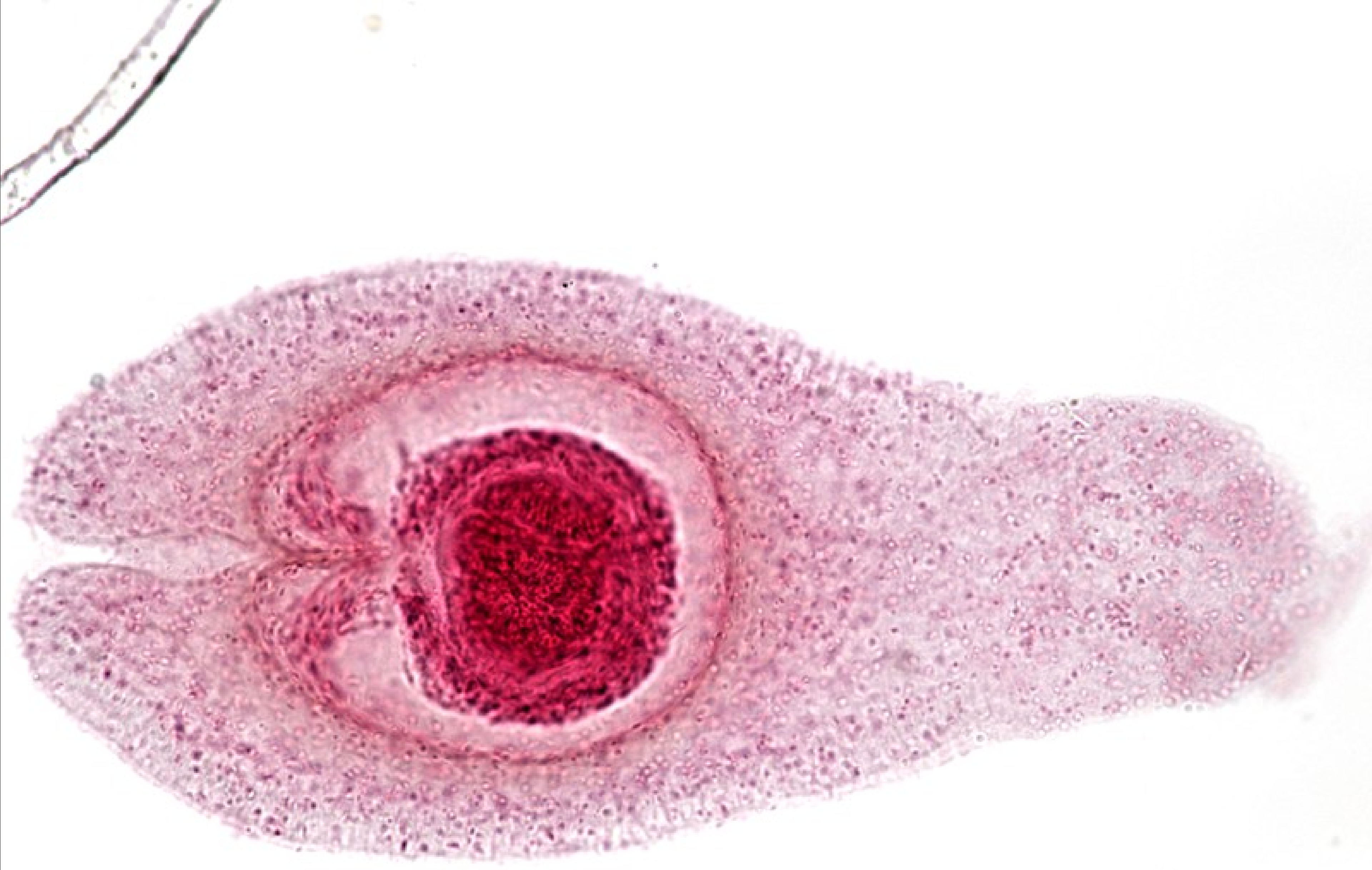
- leaf shape
- cephalic cone with shoulders
- branched intestinal ceca
- tandem, dendritic testes



FECAL SPECIMEN

Hookworm egg (*Ancylostoma duodenale* or *Necator americanus*)

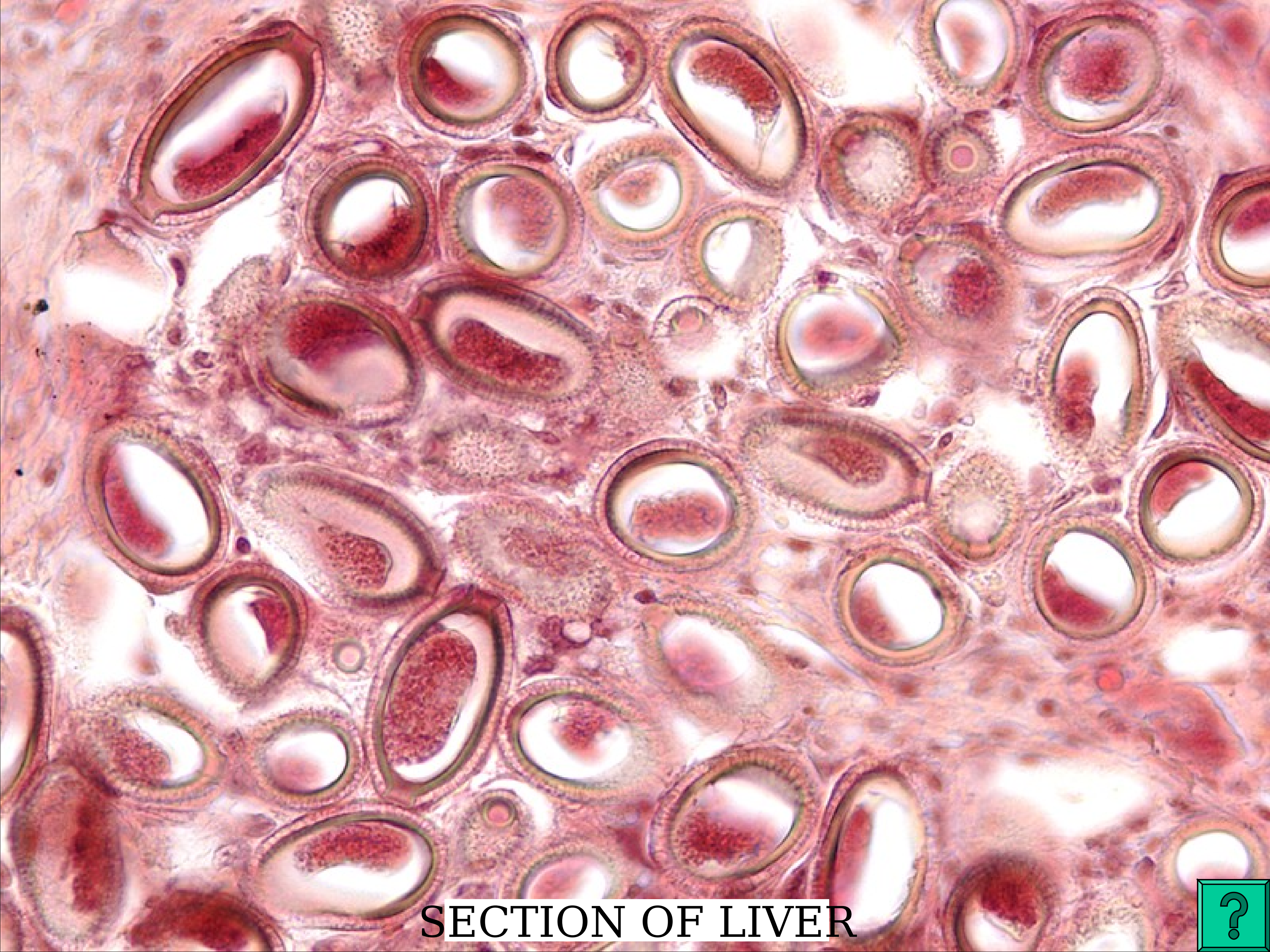
- medium size
- oval with rounded ends
- hyaline color
- very thin shell
- usually 4 or 8-cell stage embryo
- non operculate



OBJECT DISSECTED FROM

Cysticercoid of *Hymenolepis diminuta*

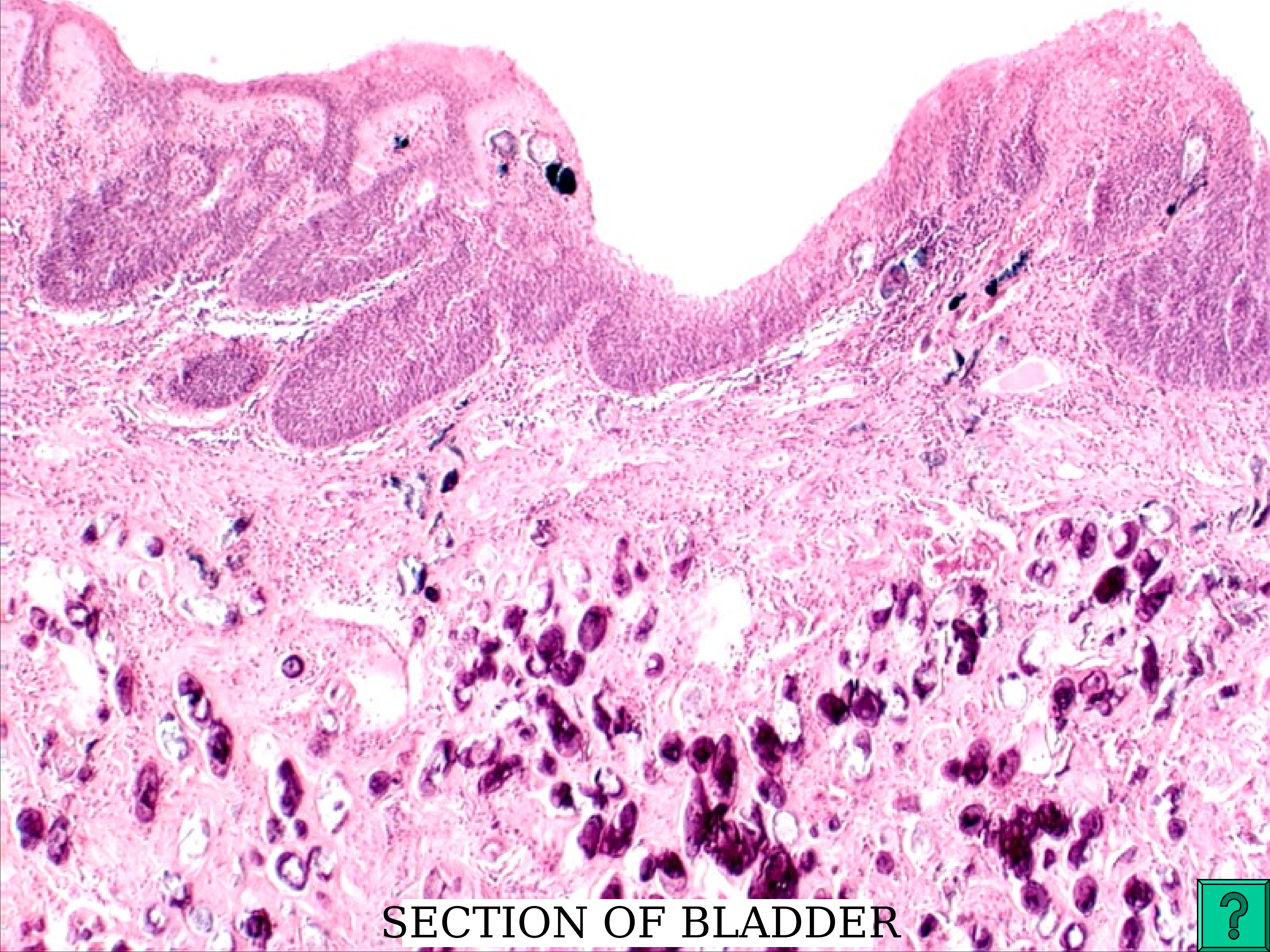
- inverted scolex, surrounded by a sheath
- absence of hooks



SECTION OF LIVER

Capillaria hepatica eggs

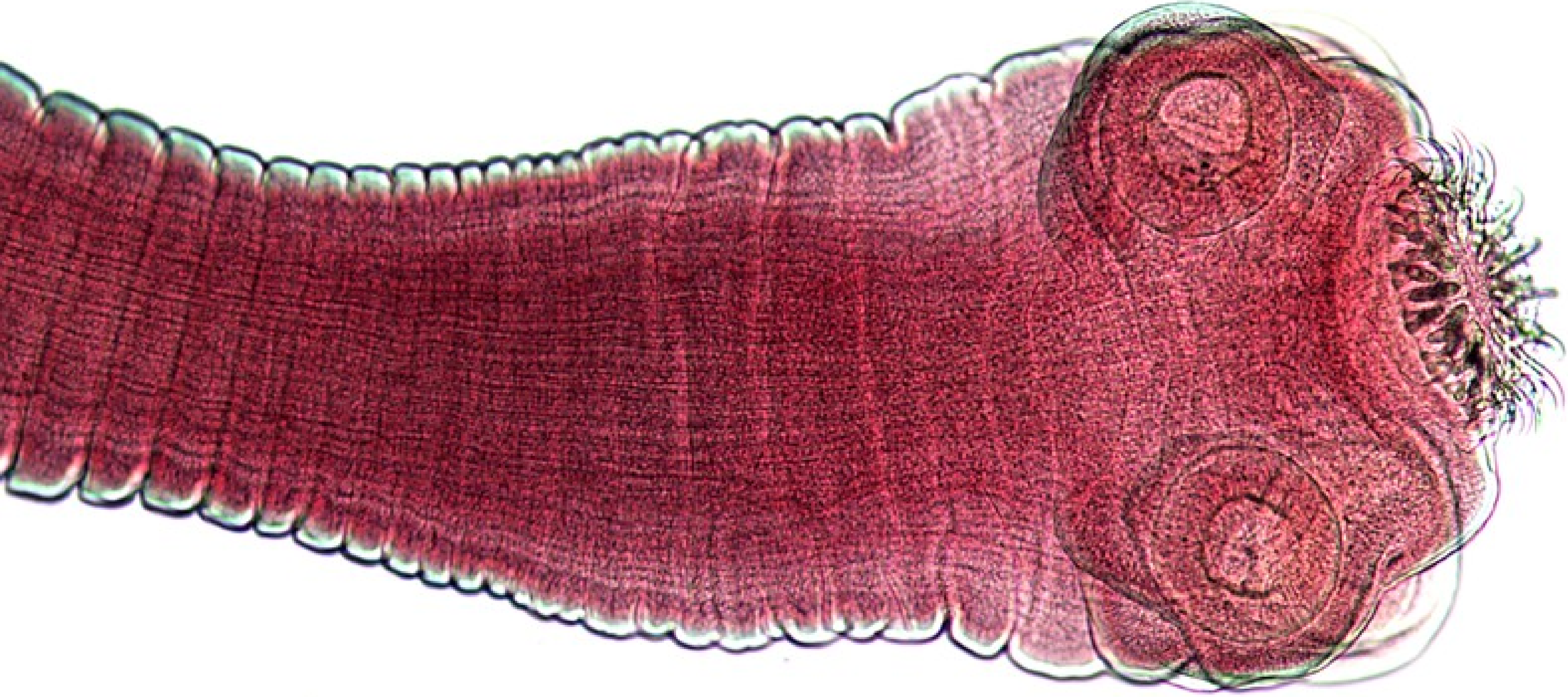
- medium sized
- barrel-shaped
- thick shell with pits or striations
- polar plugs
- unembryonated
- large masses of eggs displacing liver tissue
- relatively little inflammation



SECTION OF BLADDER

Schistosoma haematobium eggs

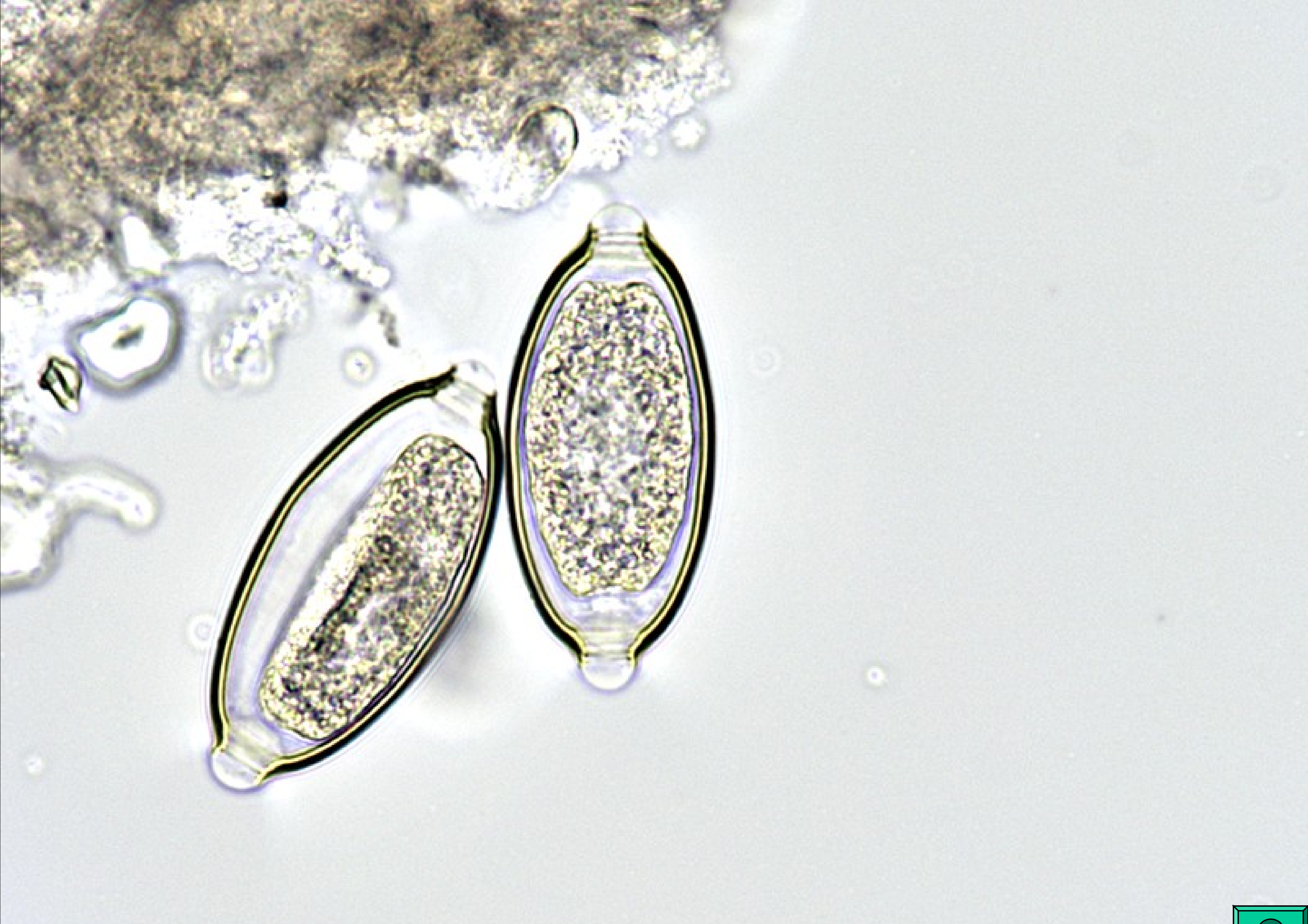
- calcified, elongate eggs in muscularis, lamina propria, and epithelium



FECAL SPECIMEN

Taenia solium scolex

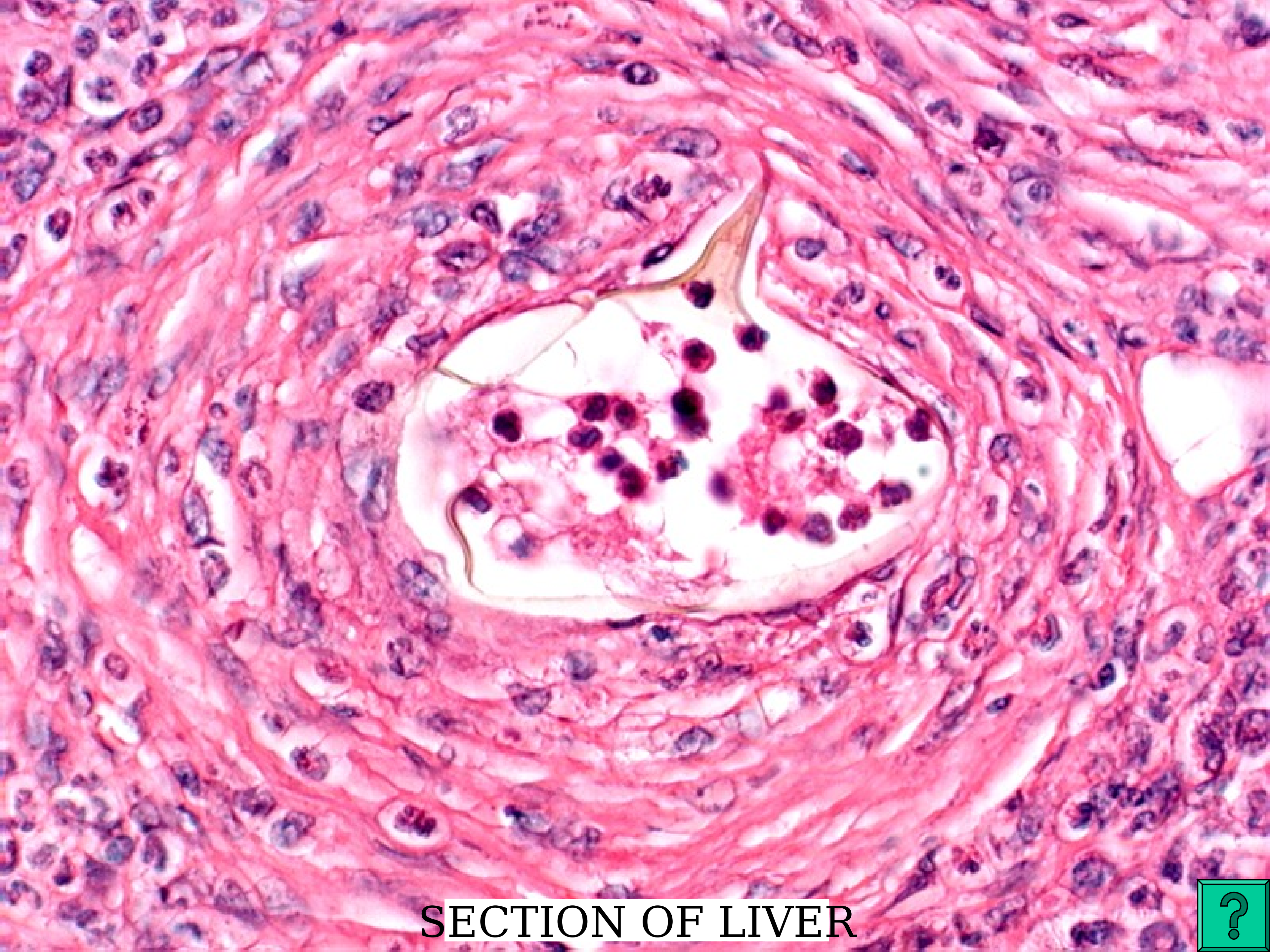
- rostellum with two rows of hooks
- 4 suckers



FECAL SPECIMEN

Trichuris trichiura eggs

- medium size
- barrel shape
- golden brown color
- polar plugs
- unembryonated
- non operculate
- smooth surface



SECTION OF LIVER

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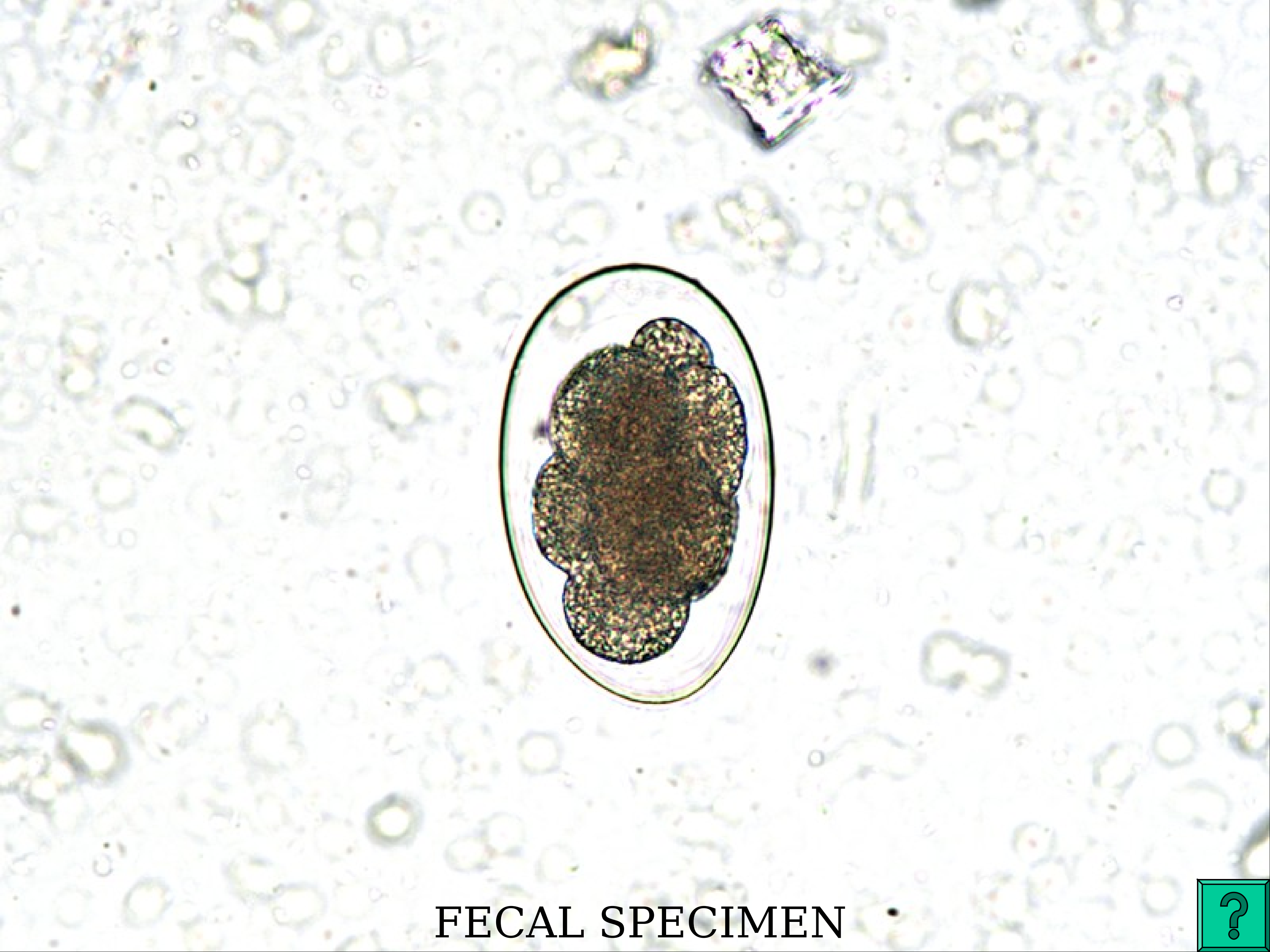
Granuloma surrounding *Schistosoma mansoni* egg

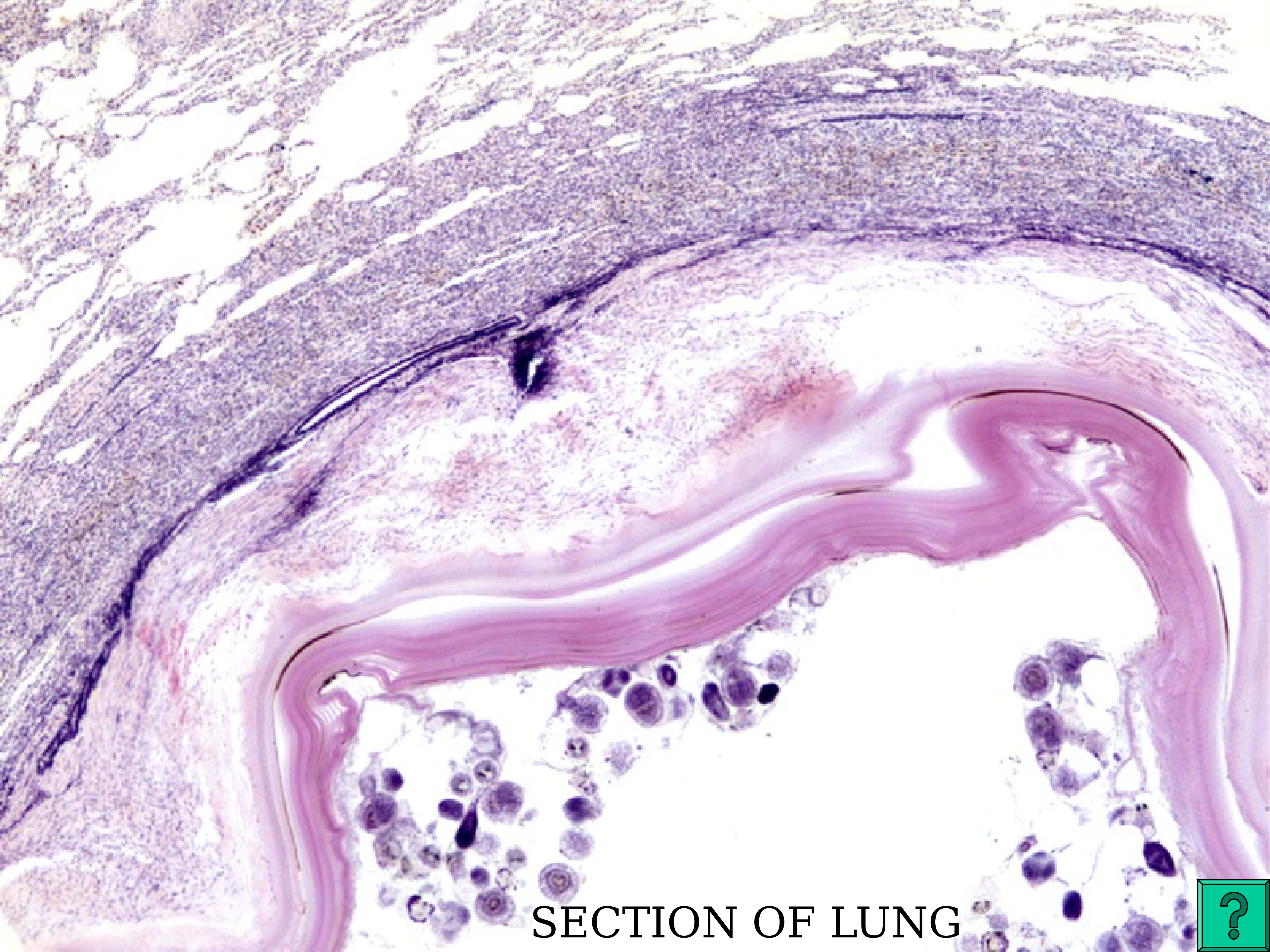
- multilayered fibrotic lesion
- egg with prominent lateral spine



FECAL SPECIMEN

Trichostrongylus spp. egg

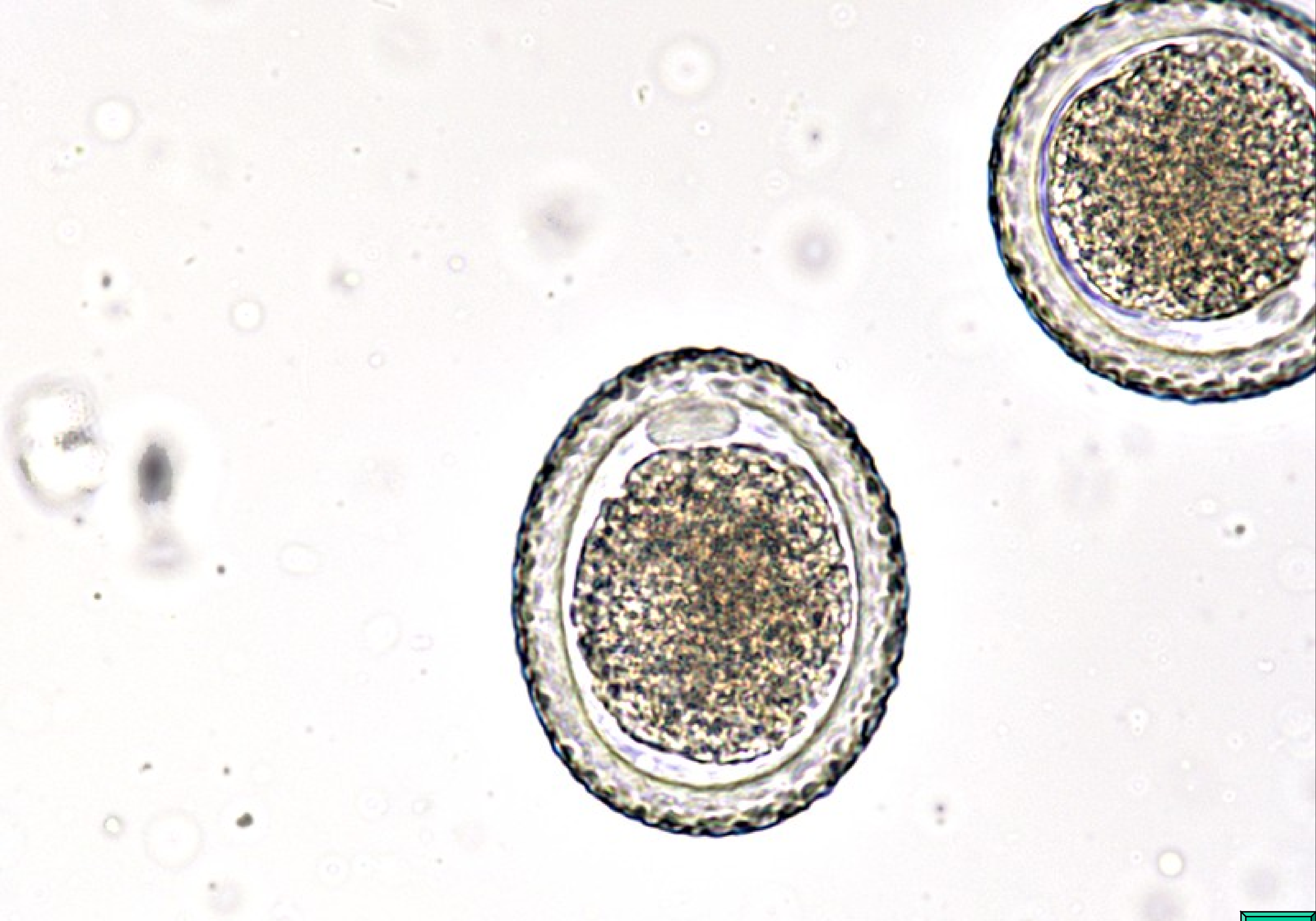
- medium size, longer than hookworm egg
- oval shape, slightly pointed at one end
- thin shell
- hyaline color
- unembryonated, usually with more cells than hookworm egg
- non operculate



SECTION OF LUNG

Unilocular hydatid cyst of *Echinococcus granulosus*

- multilayered cyst wall with thick, acellular ectocyst
- germinal layer with brood capsule containing protoscolices



FECAL SPECIMEN FROM

Toxocara canis egg

- round to oval
- pitted, golf ball-like surface
- light brown color
- unembryonated in freshly passed feces
- non operculate

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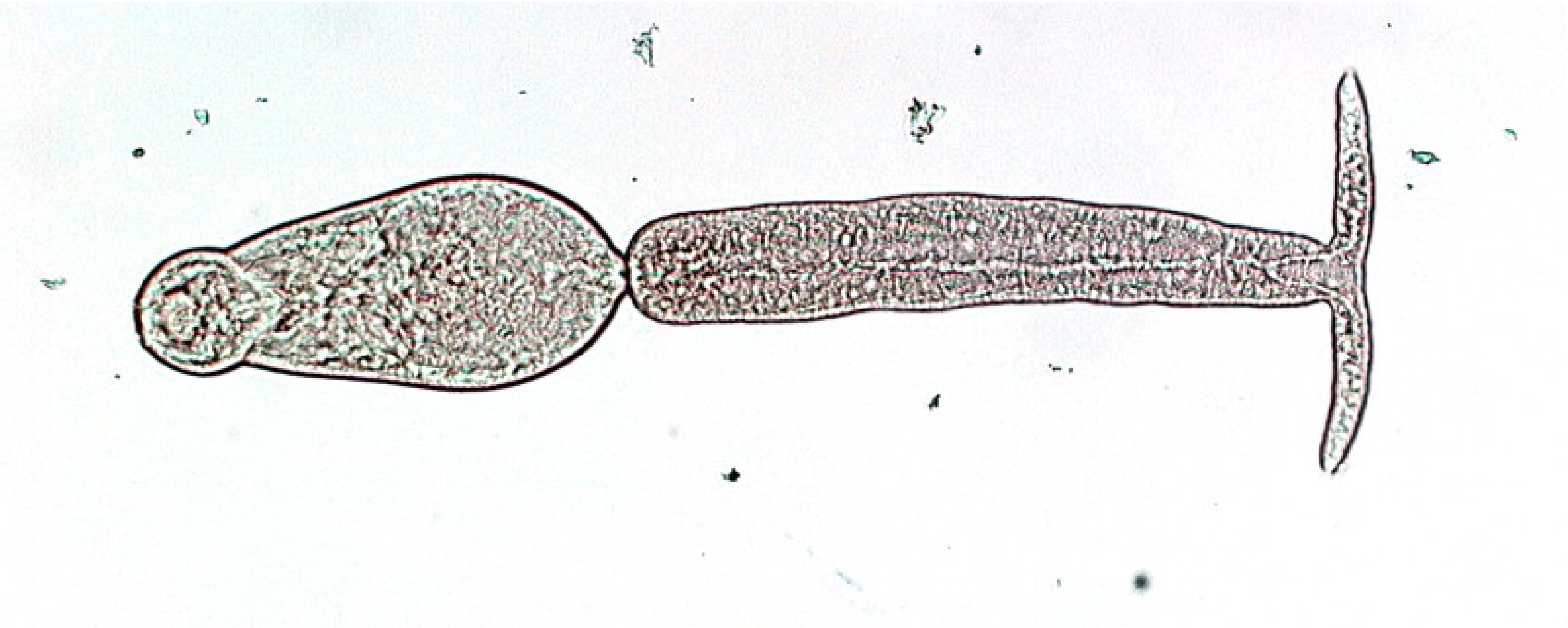
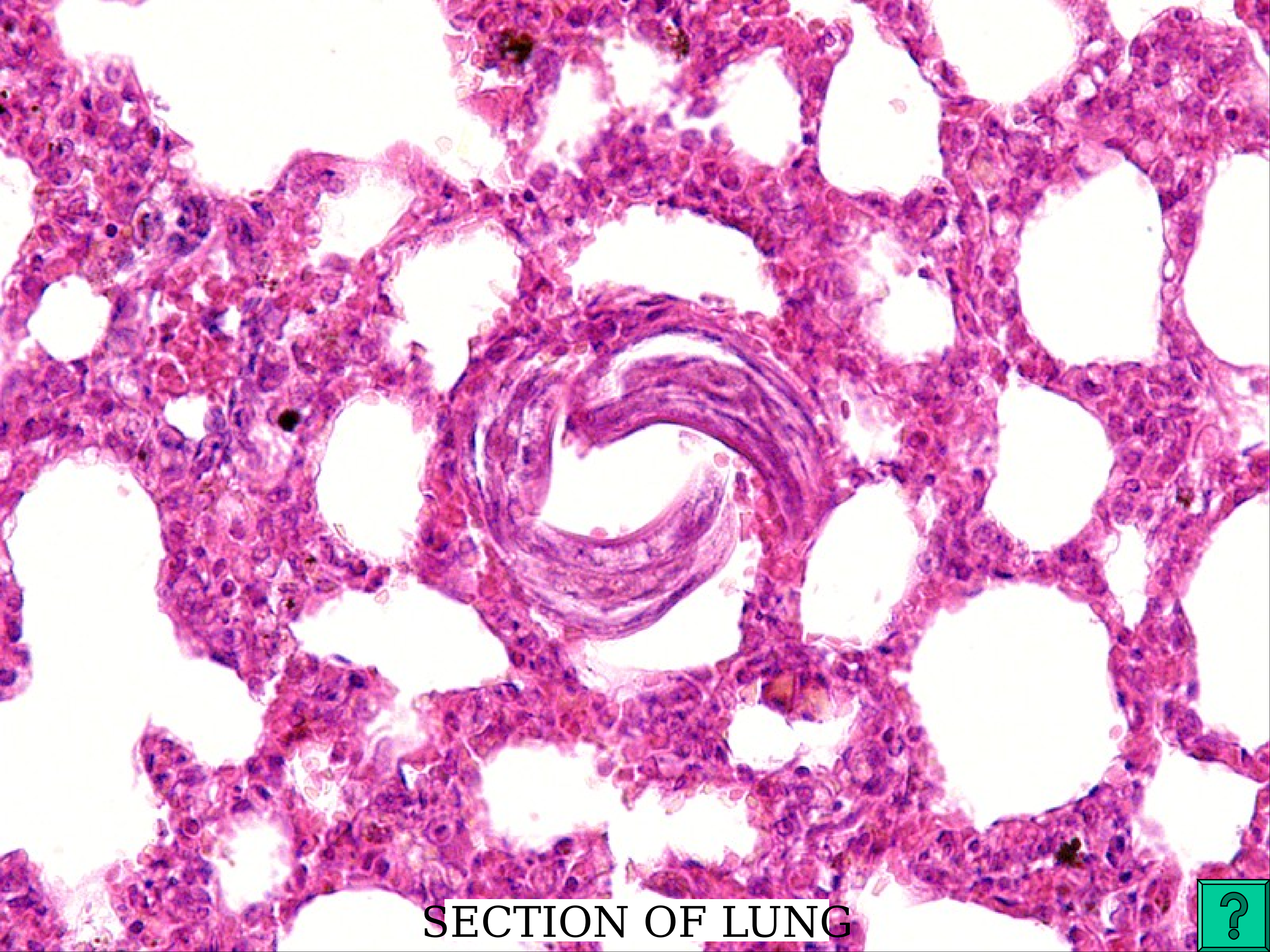


WATER SAMPLE

Schistosoma spp. cercaria

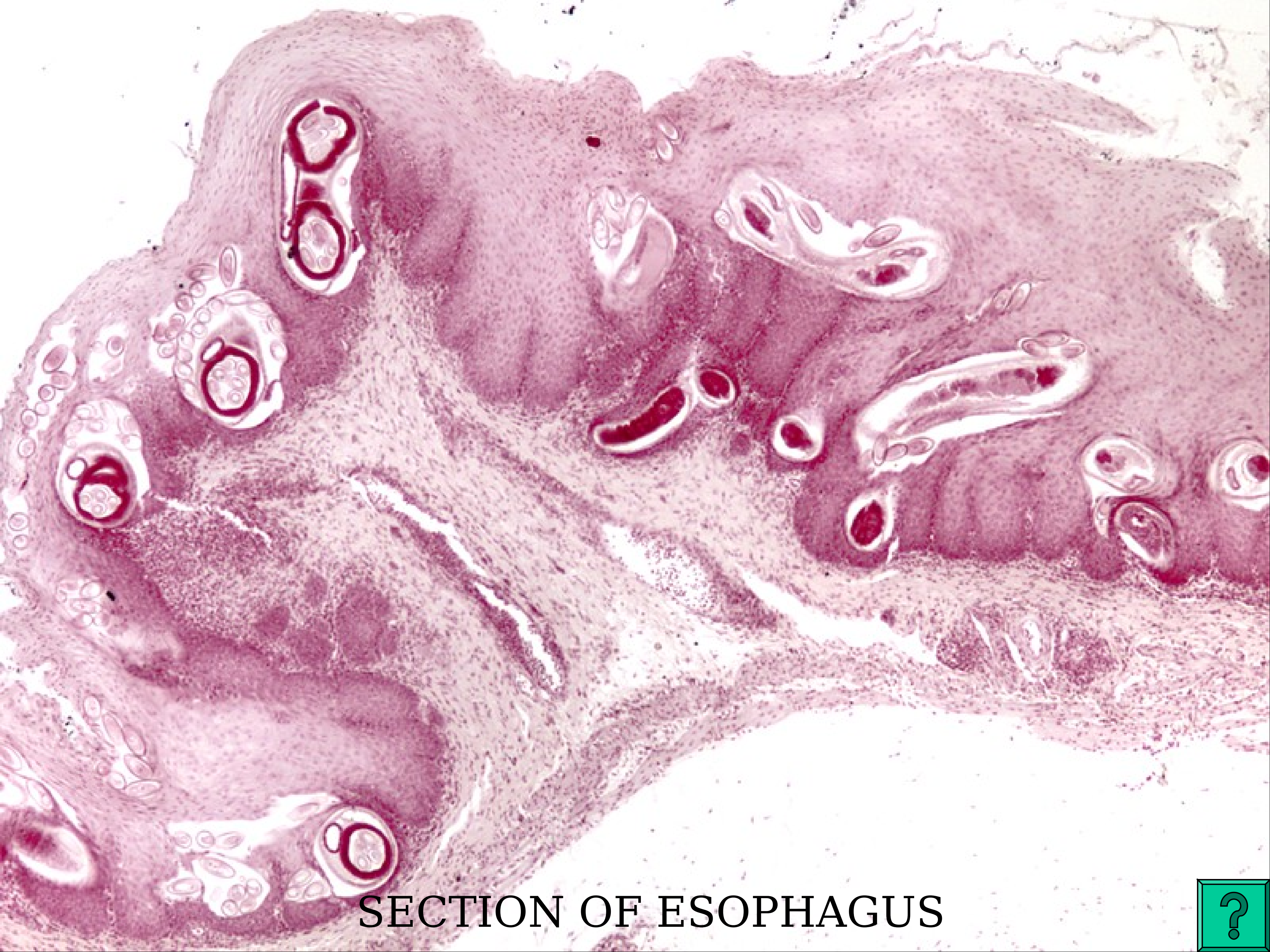
- forked tail
- apharyngeate
- pre- and post-acetabular penetration glands



SECTION OF LUNG

Ascaris lumbricoides larva

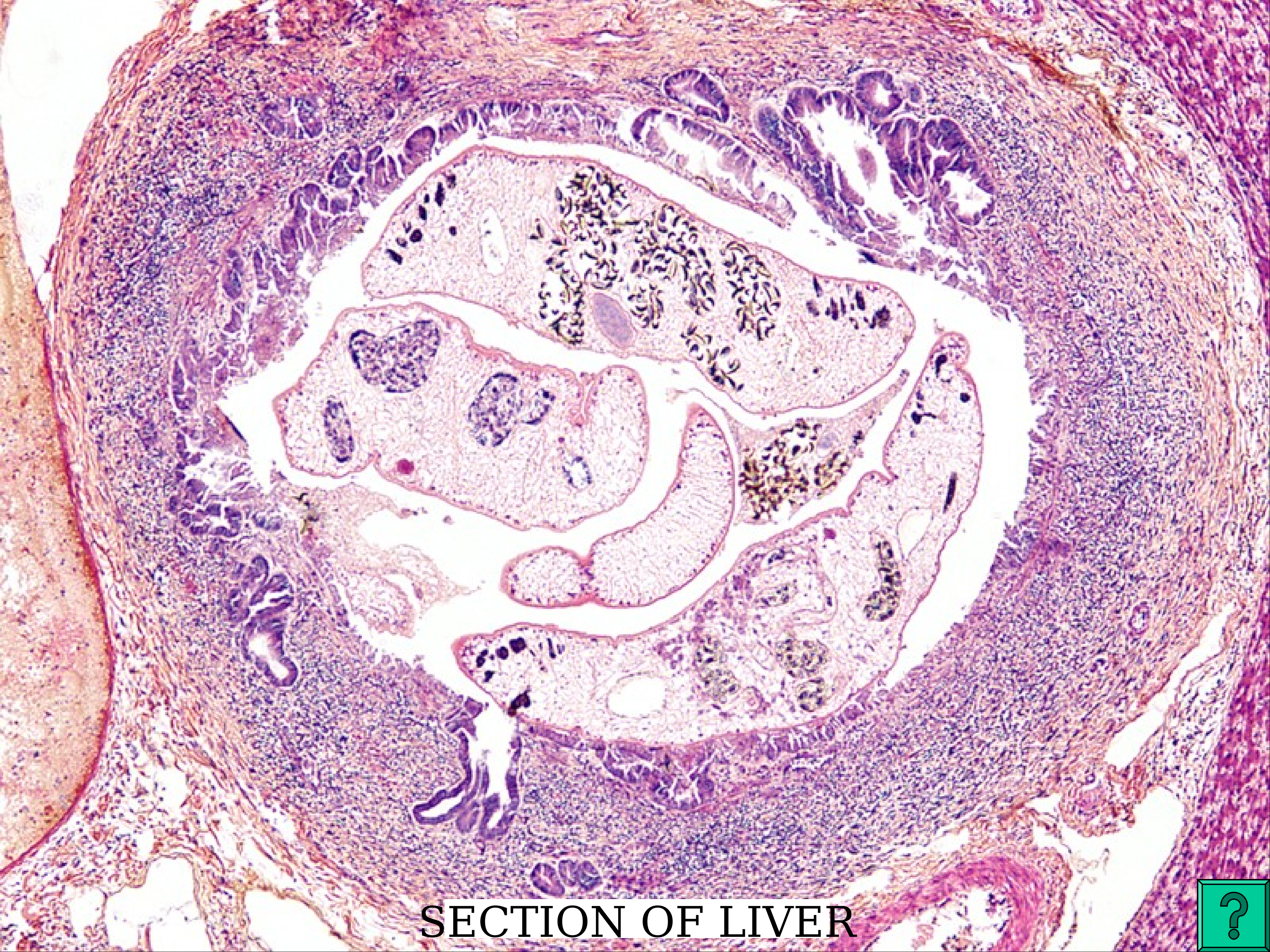
- nematode larvae breaking into alveoli
- marked inflammation
- alternative identifications: larvae of hookworms or *Strongyloides stercoralis*



SECTION OF ESOPHAGUS

Gongylonema sp. adult and eggs

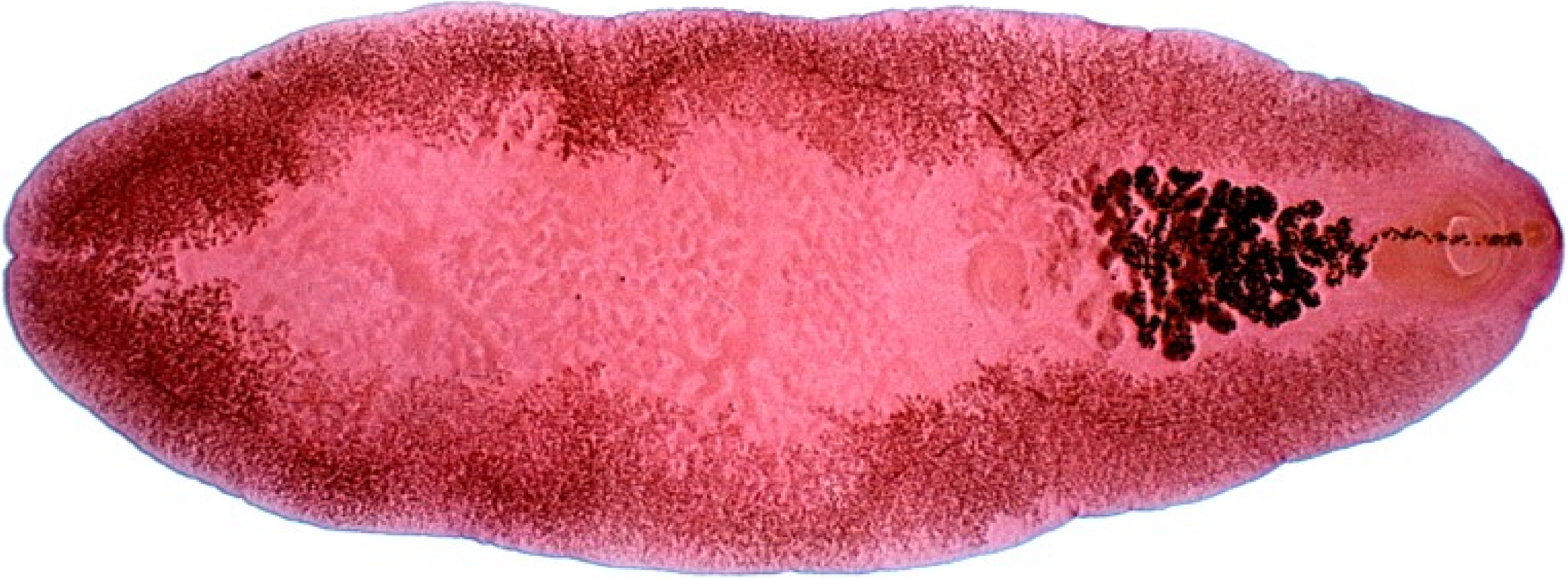
- multiple sections of adult nematode and eggs in esophageal epithelium



SECTION OF LIVER

Clonorchis sinensis adults in bile duct

- cross sections of trematodes (dorsoventrally flattened shape, acoelomate, no cuticle, presence of digestive tract)
- unbranched intestinal ceca
- could also be *Opisthorchis* spp. or *Dicrocoelium dendriticum*



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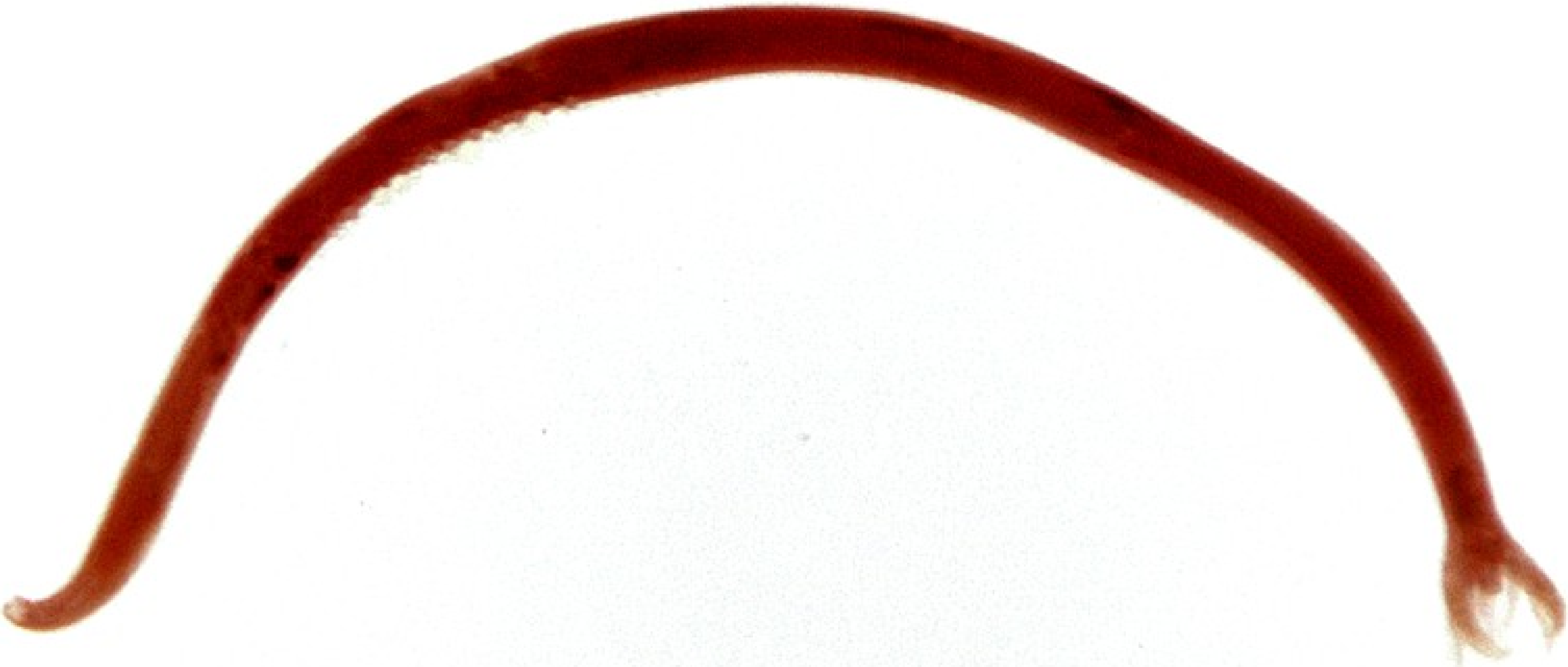
Fasciolopsis buski adult

- absence of cephalic cone and shoulders
- unbranched intestinal ceca
- dendritic, tandem testes



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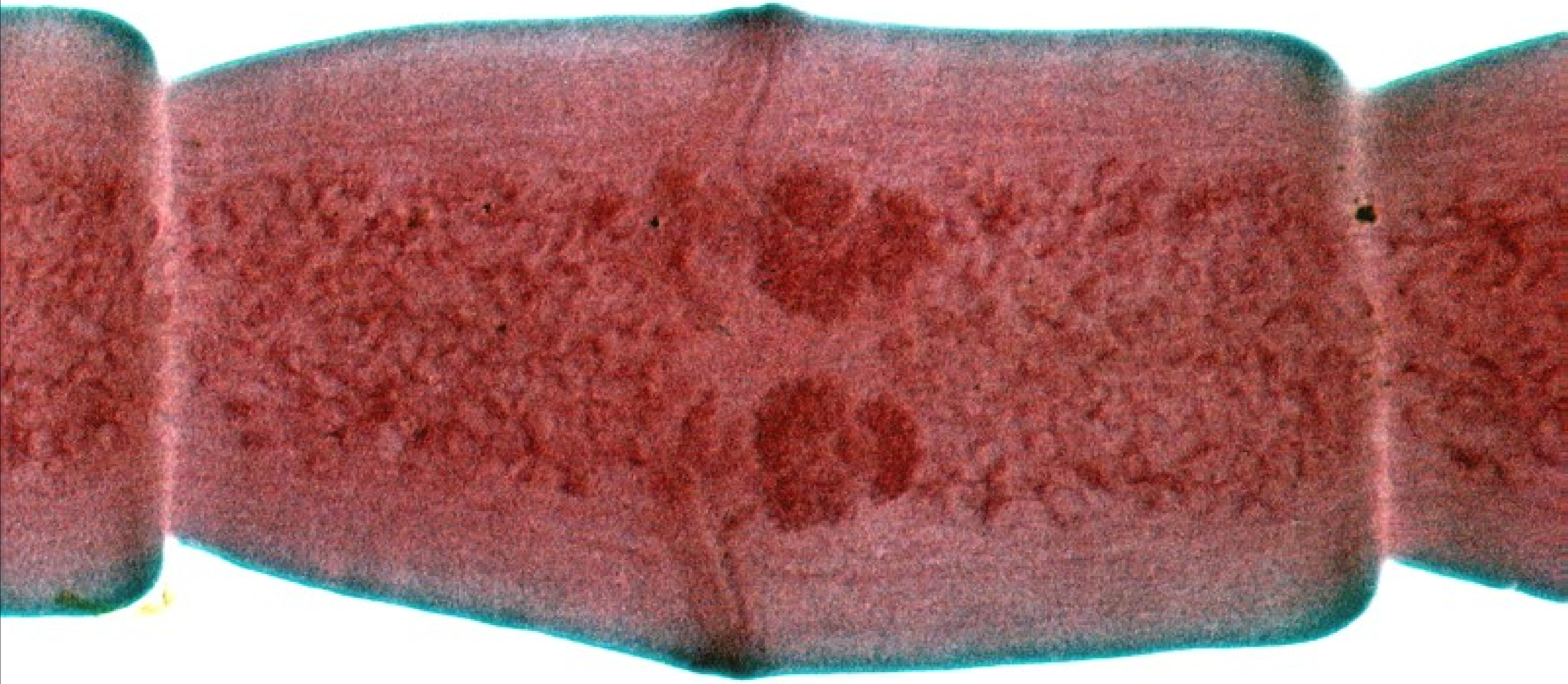
Male hookworm

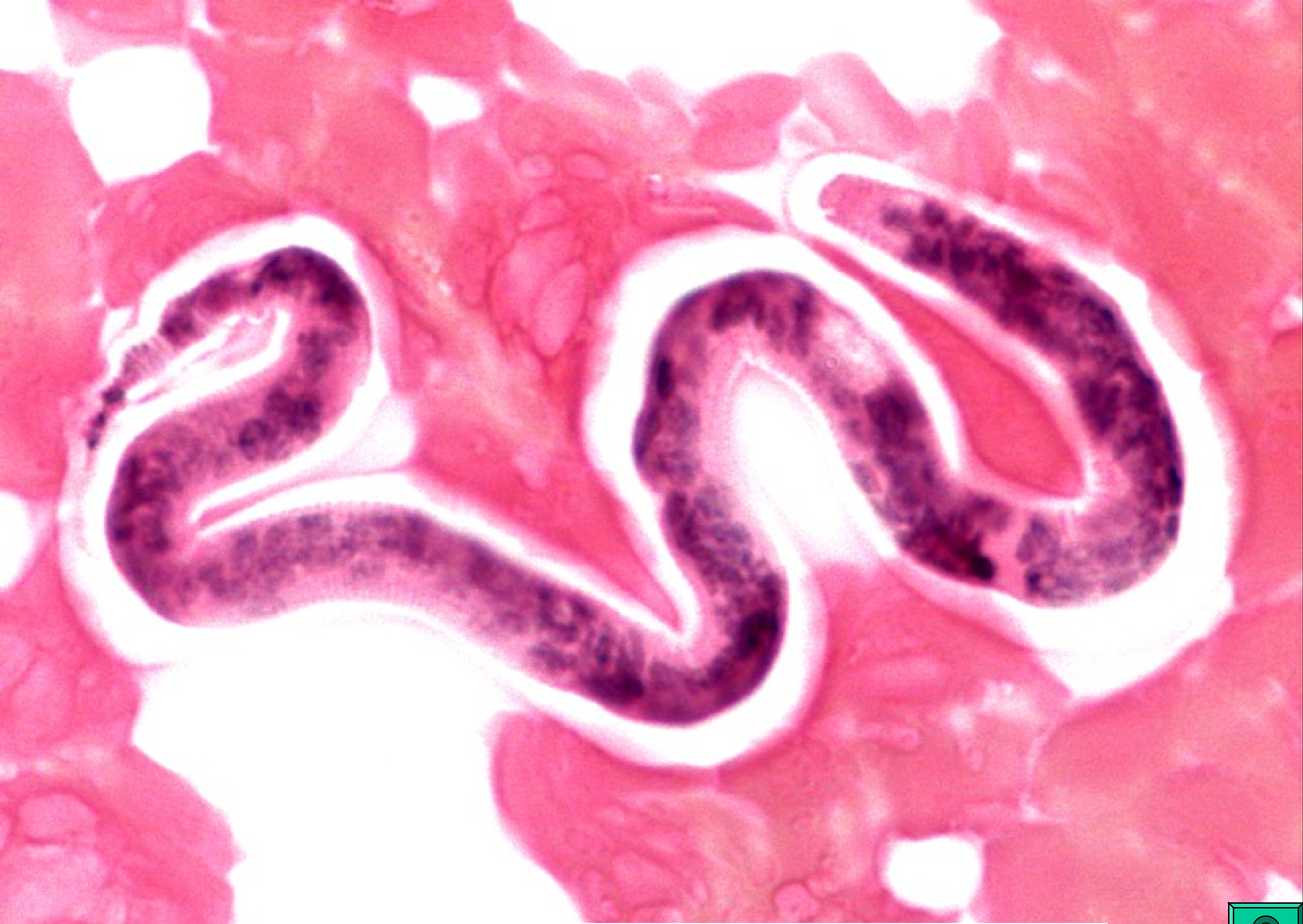
- dorsal curvature of anterior end
- copulatory bursa



FECAL SPECIMEN

Dipylidium caninum mature proglottid

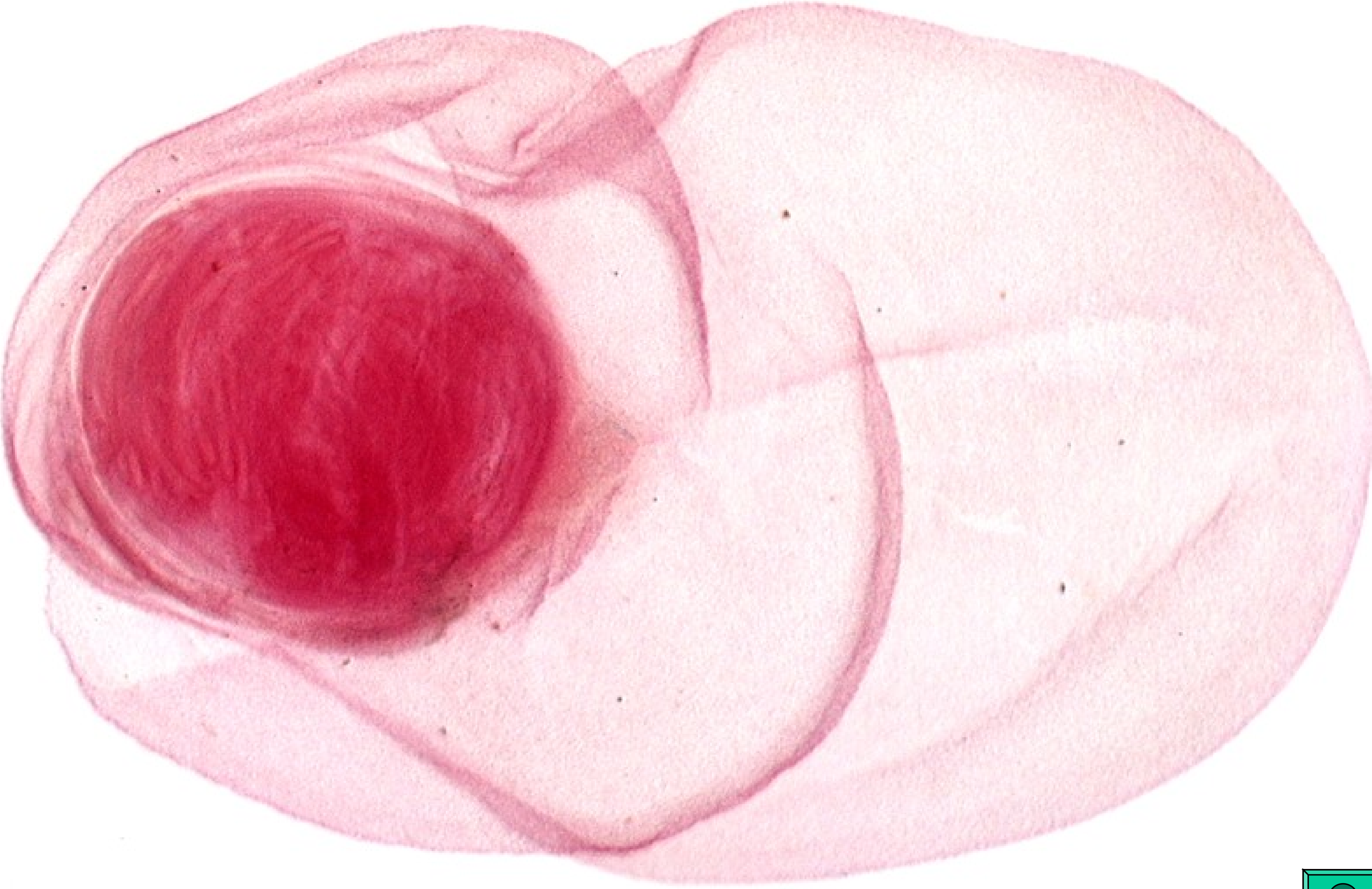
- elongate proglottid
- two genital pores
- two ovaries



PERIPHERAL BLOOD SMEAR FROM

Dirofilaria immitis microfilaria

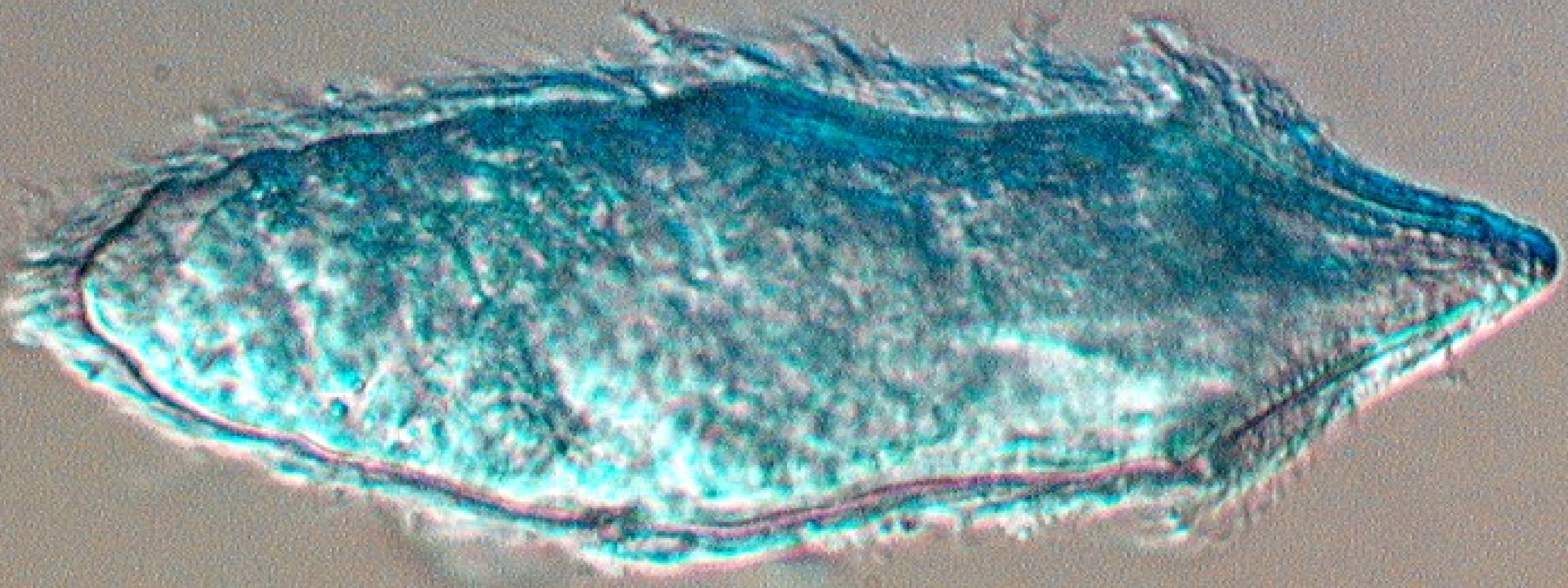
- nematode embryo in peripheral blood
- short cephalic space
- nuclei do not extend to the tip of tail (pointed end)



OBJECT REMOVED FROM

Taenia solium cysticercus

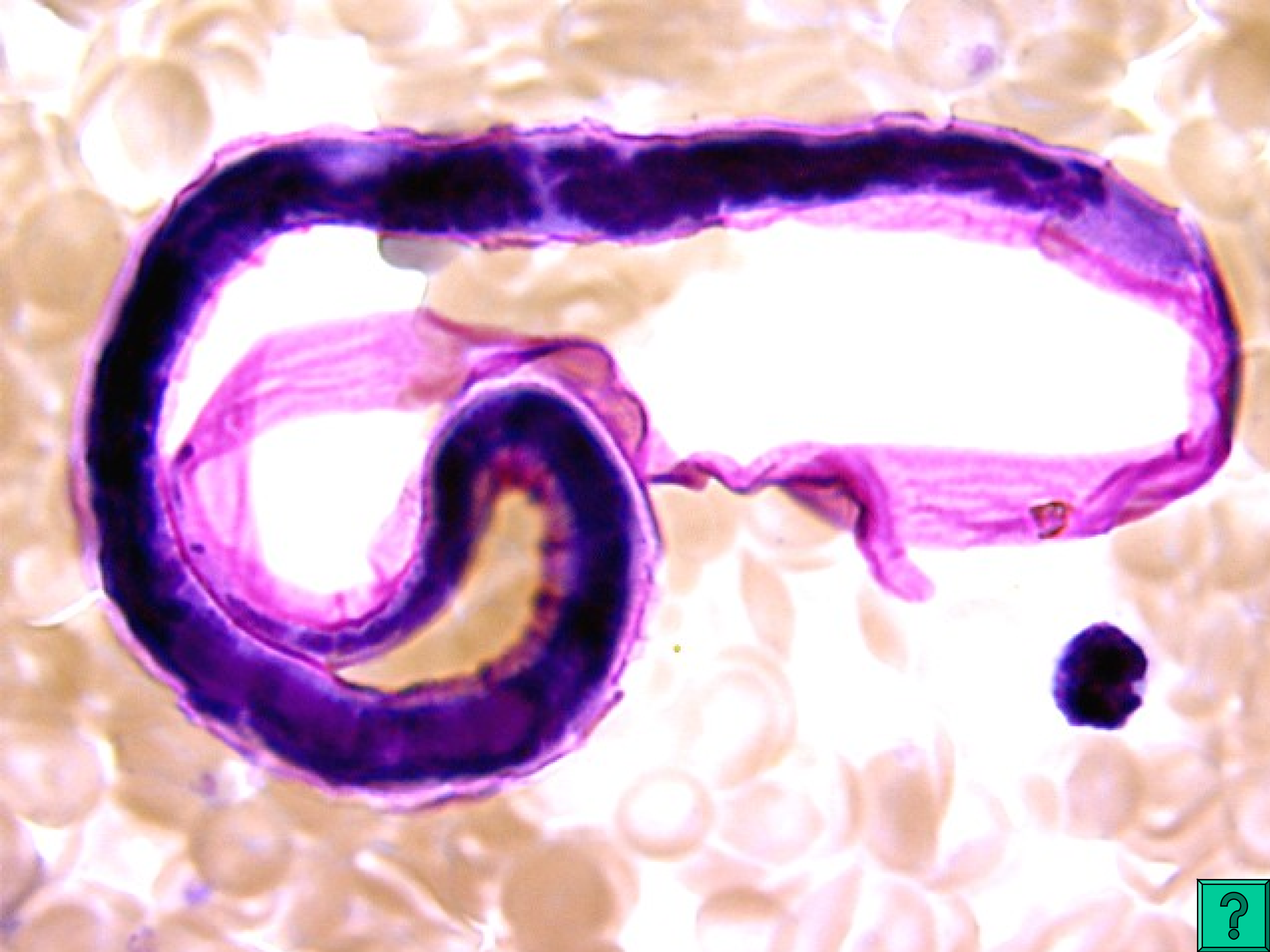
- scolex invaginated and introverted in a fluid-filled bladder



WATER SAMPLE

Trematode miracidium

- multicellular, ciliated organism
- narrow anterior end
- lateral papillae
- posterior germinal cells



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Microfilaria of *Brugia malayi*

- sheathed
- long cephalic space
- compact column of nuclei
- terminal and subterminal nuclei in tail

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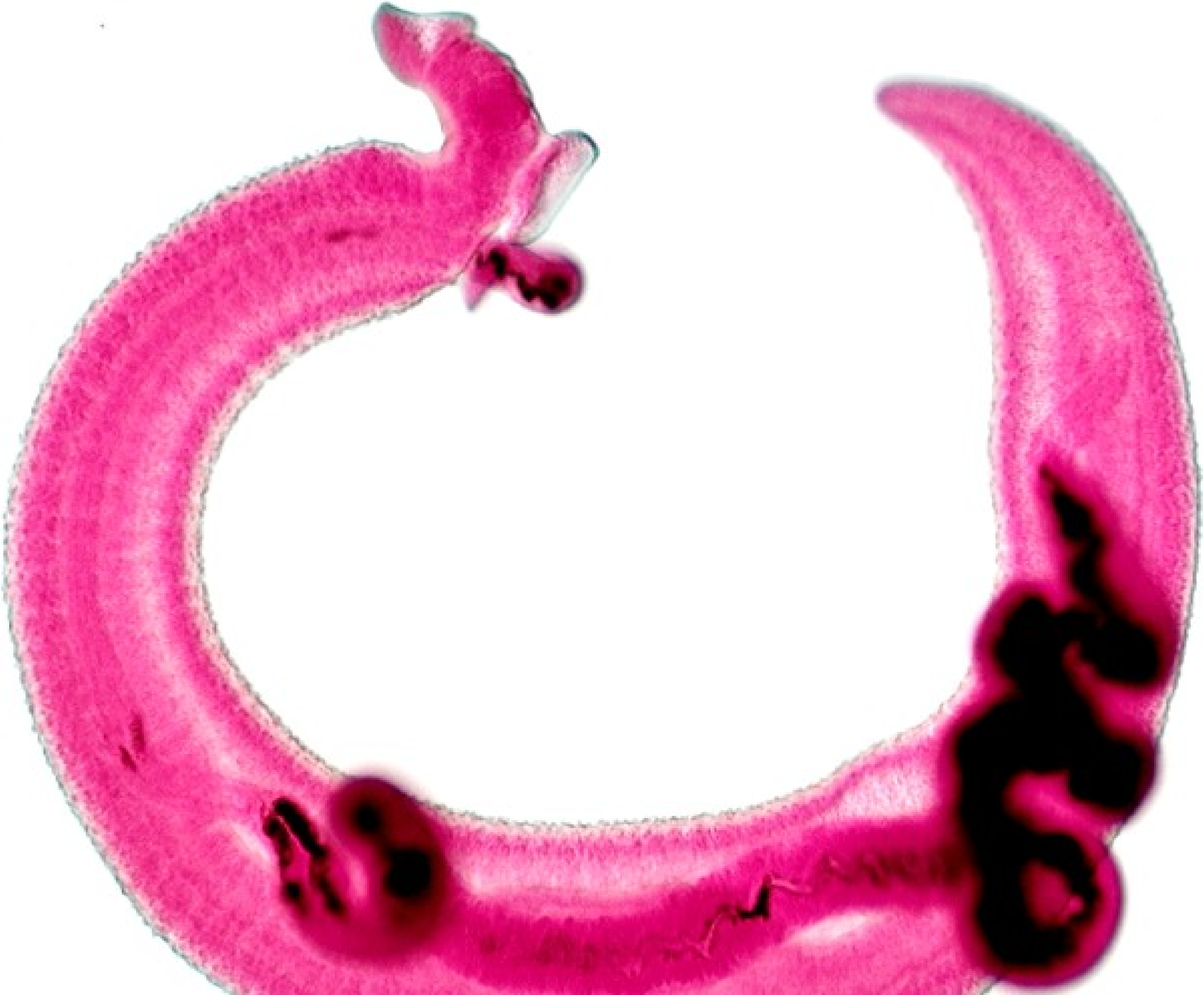

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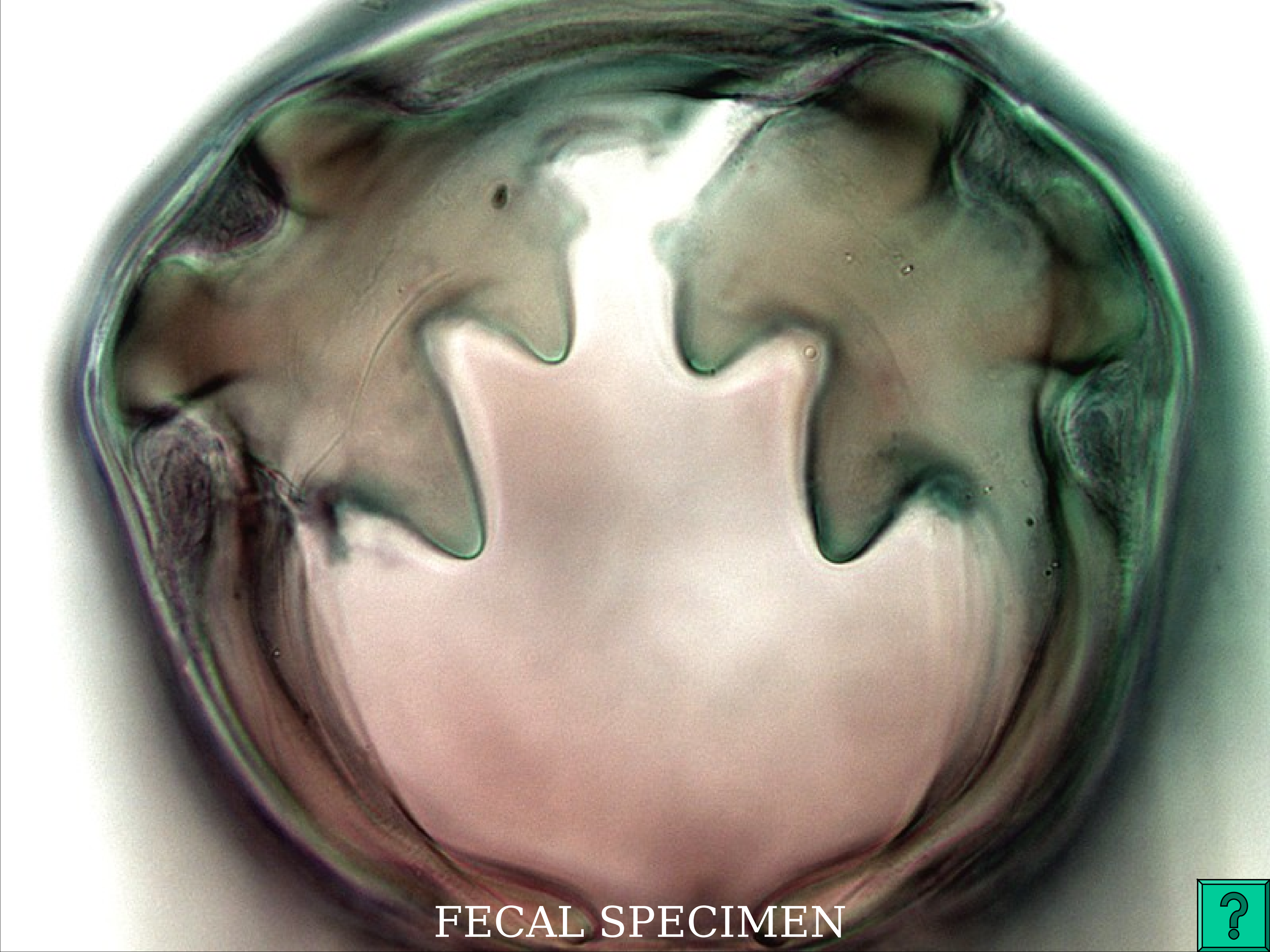
Schistosoma mansoni, male and female *in copula*

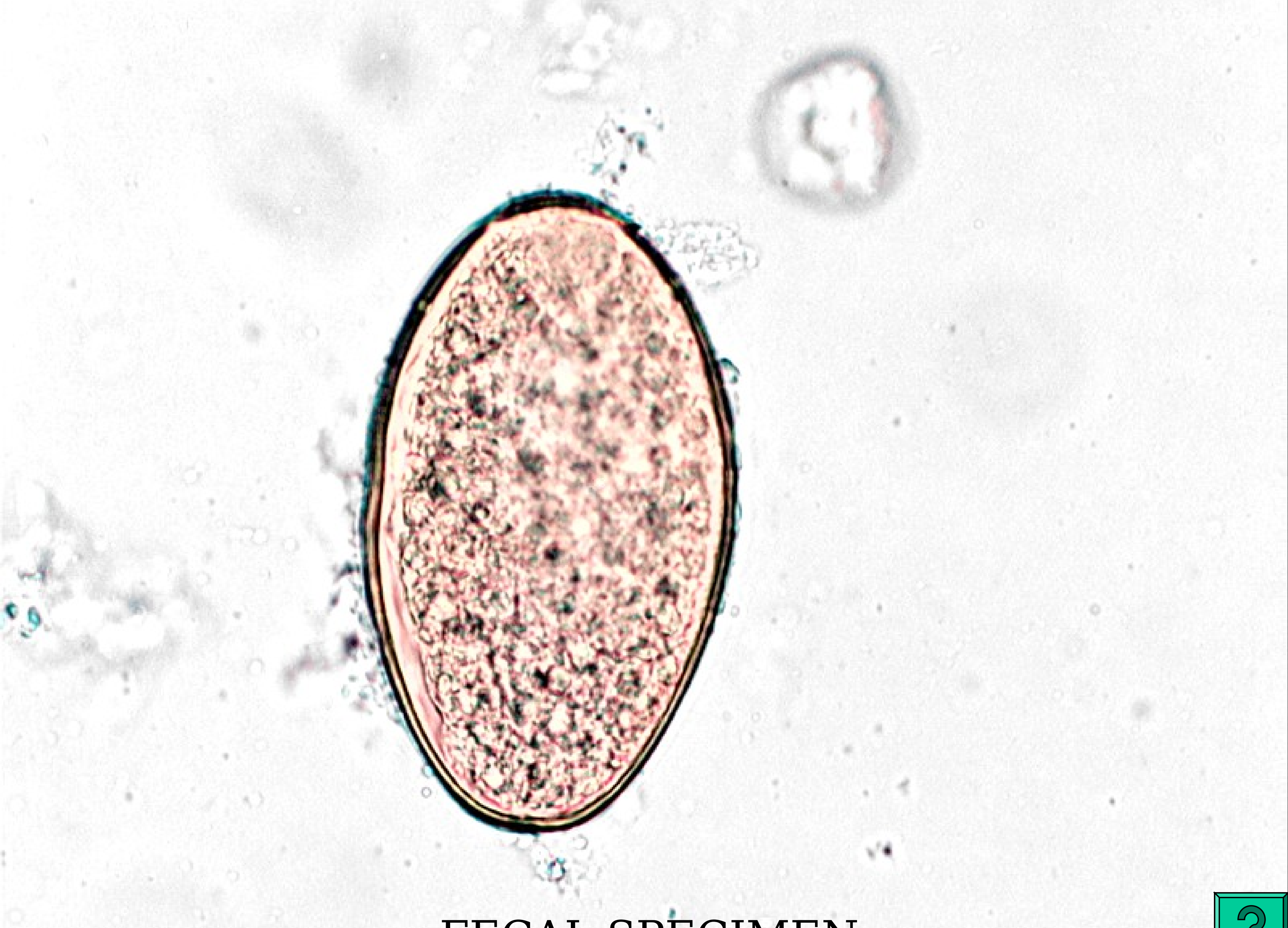
- slender female within gynecophoral canal of male
- grossly tuberculated tegument of male



FECAL SPECIMEN

Ancylostoma duodenale anterior end

- ventral teeth in buccal cavity



FECAL SPECIMEN

Fasciola hepatica egg

- large size
- oval shape
- yellowish brown color
- unembryonated
- indistinct, small operculum

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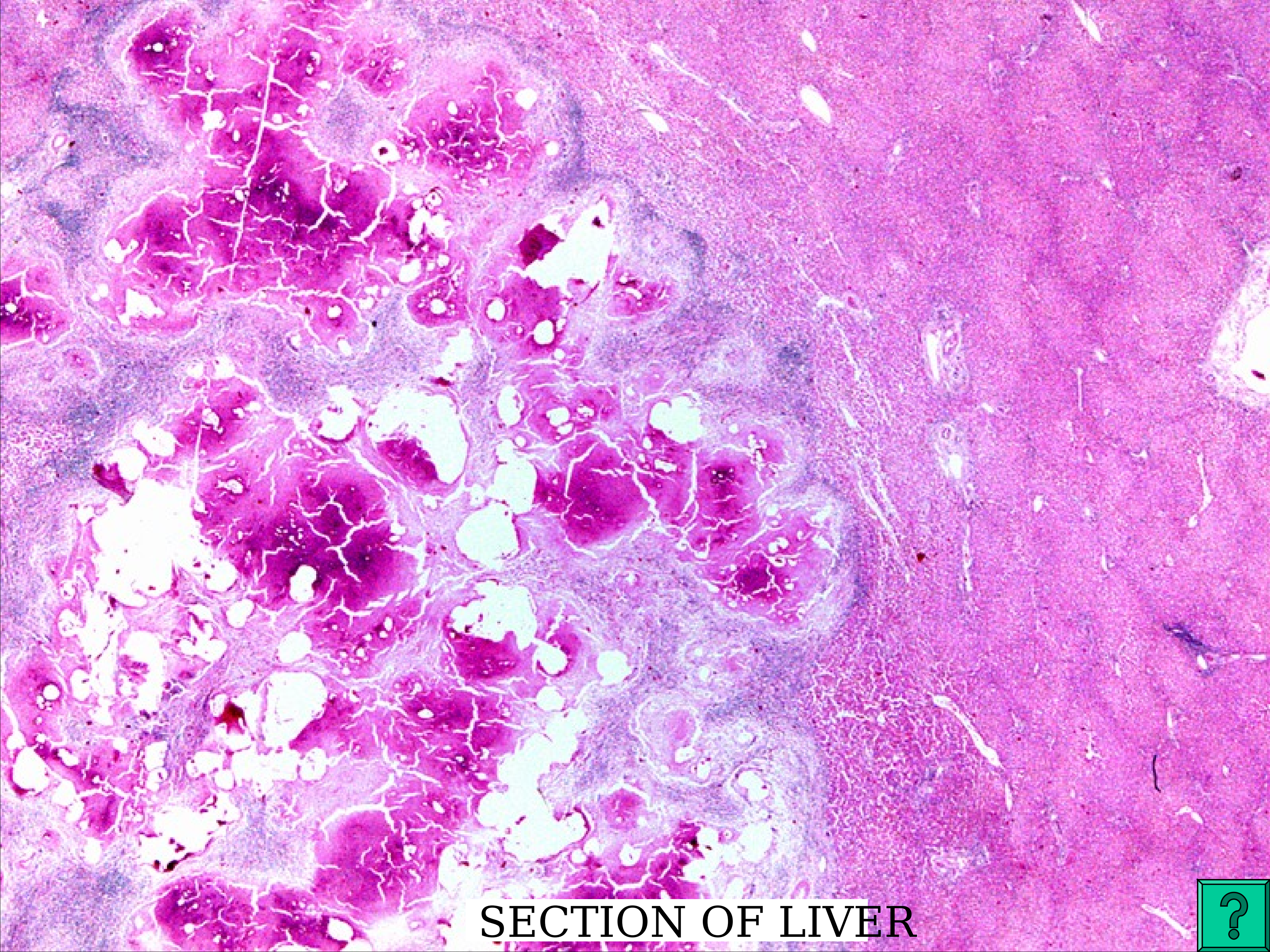
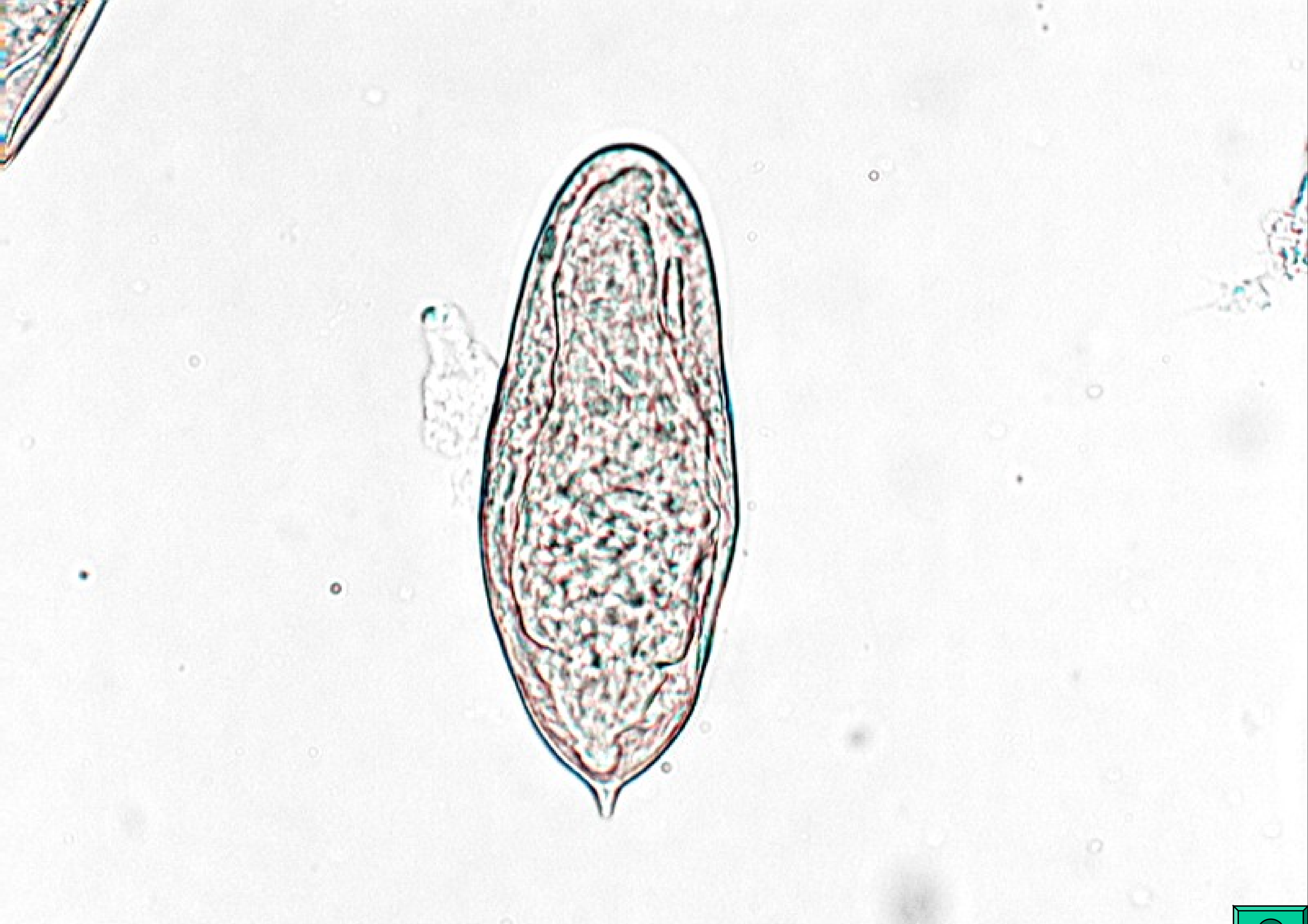


SECTION OF LIVER

Multilocular hydatid cyst of *Echinococcus multilocularis*

- invasive growth
- necrotic central region
- absence of protoscolices
- absence of thick multilayered ectocyst



URINE SPECIMEN

Schistosoma haematobium egg

- large, elongate egg
- hyaline to light yellow color
- prominent terminal spine
- miracidium within egg
- non operculate

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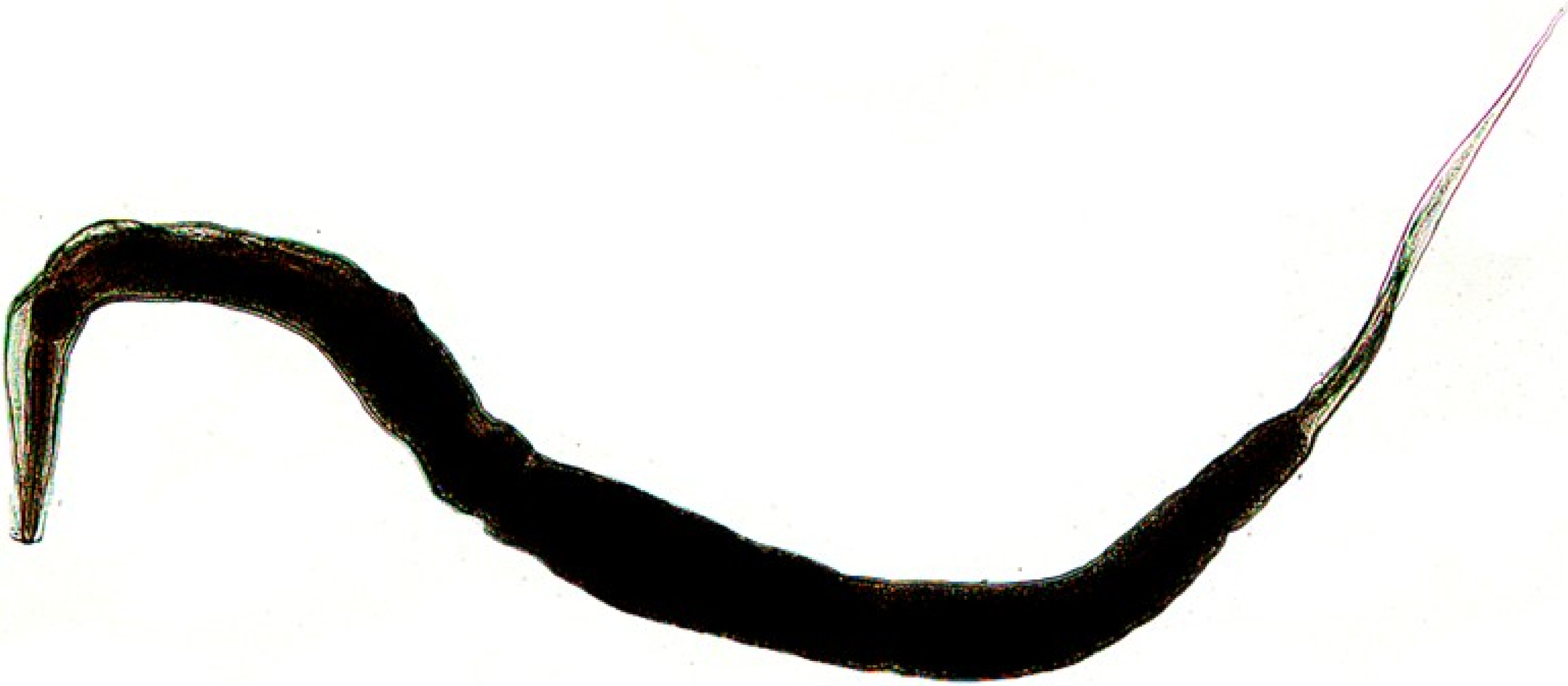
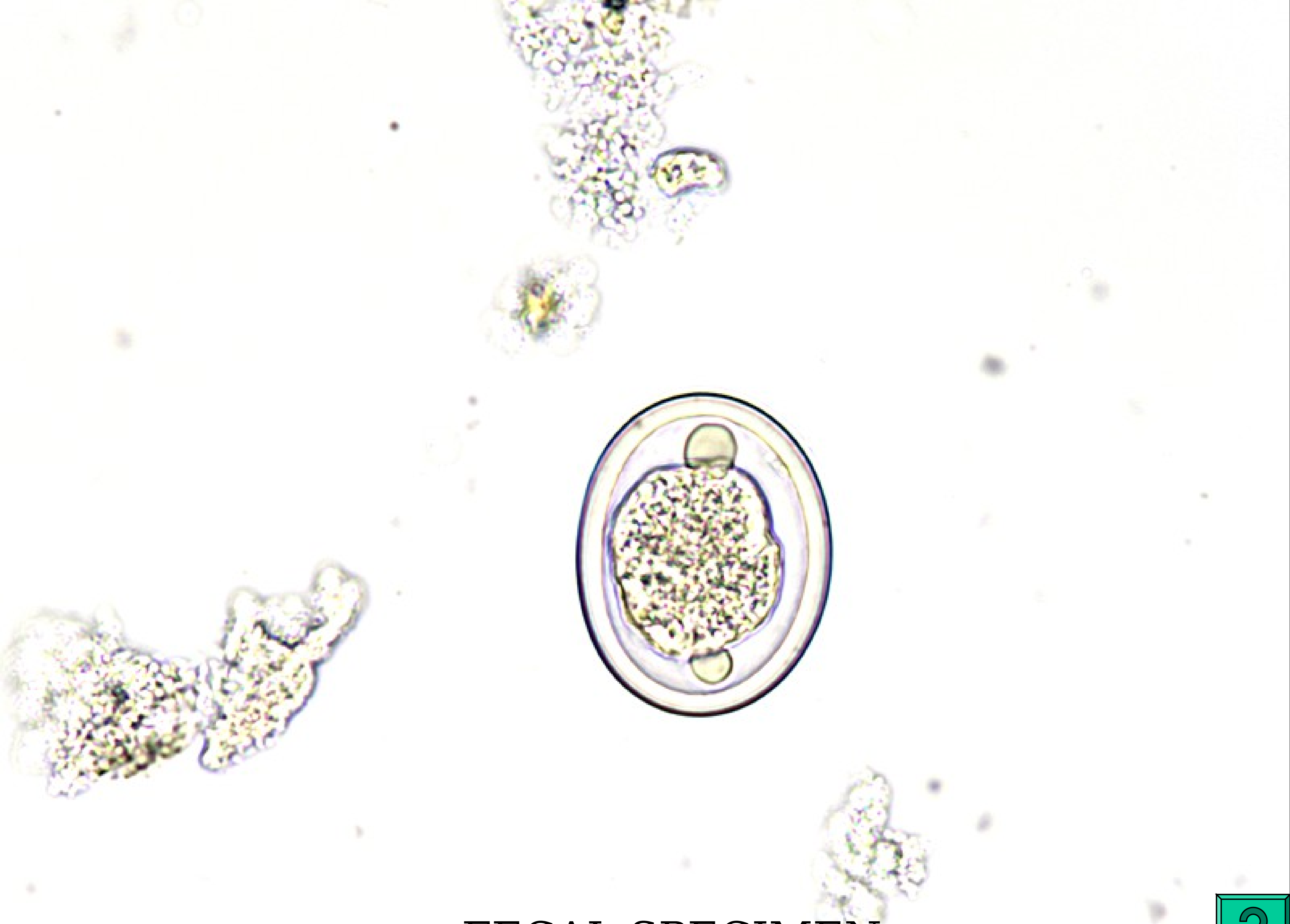


Enterobius vermicularis adult female

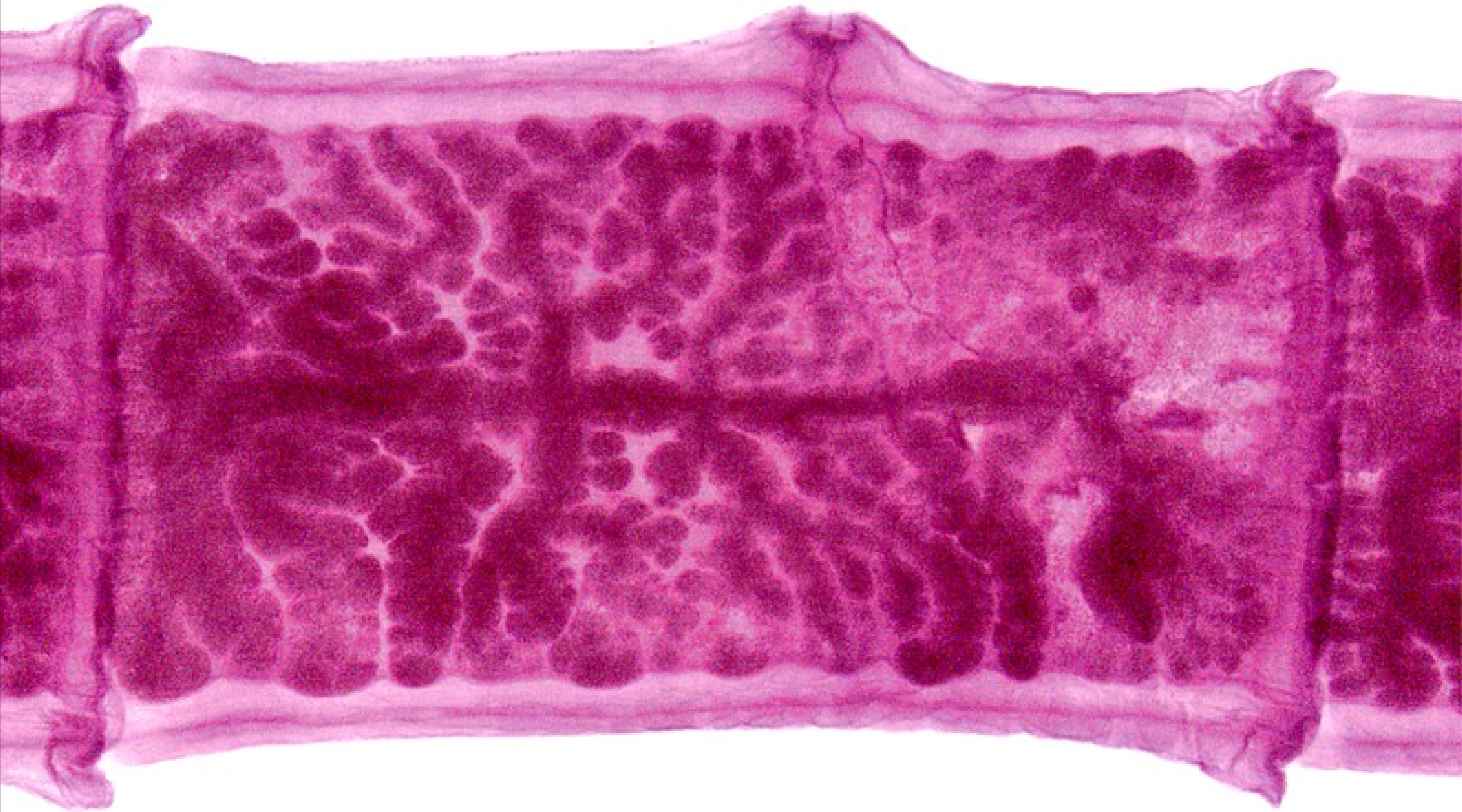
- pointed tail
- swollen cuticle at anterior end
- prominent esophageal end bulb



FECAL SPECIMEN

Ascaris lumbricoides decorticated egg

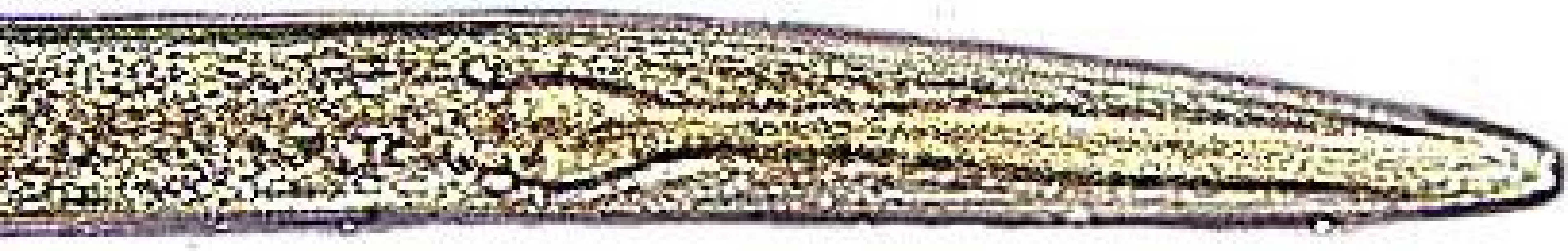
- oval to round shape
- thick shell
- hyaline to light brown color
- unembryonated
- non operculate



FECAL SPECIMEN

Taenia solium gravid proglottid

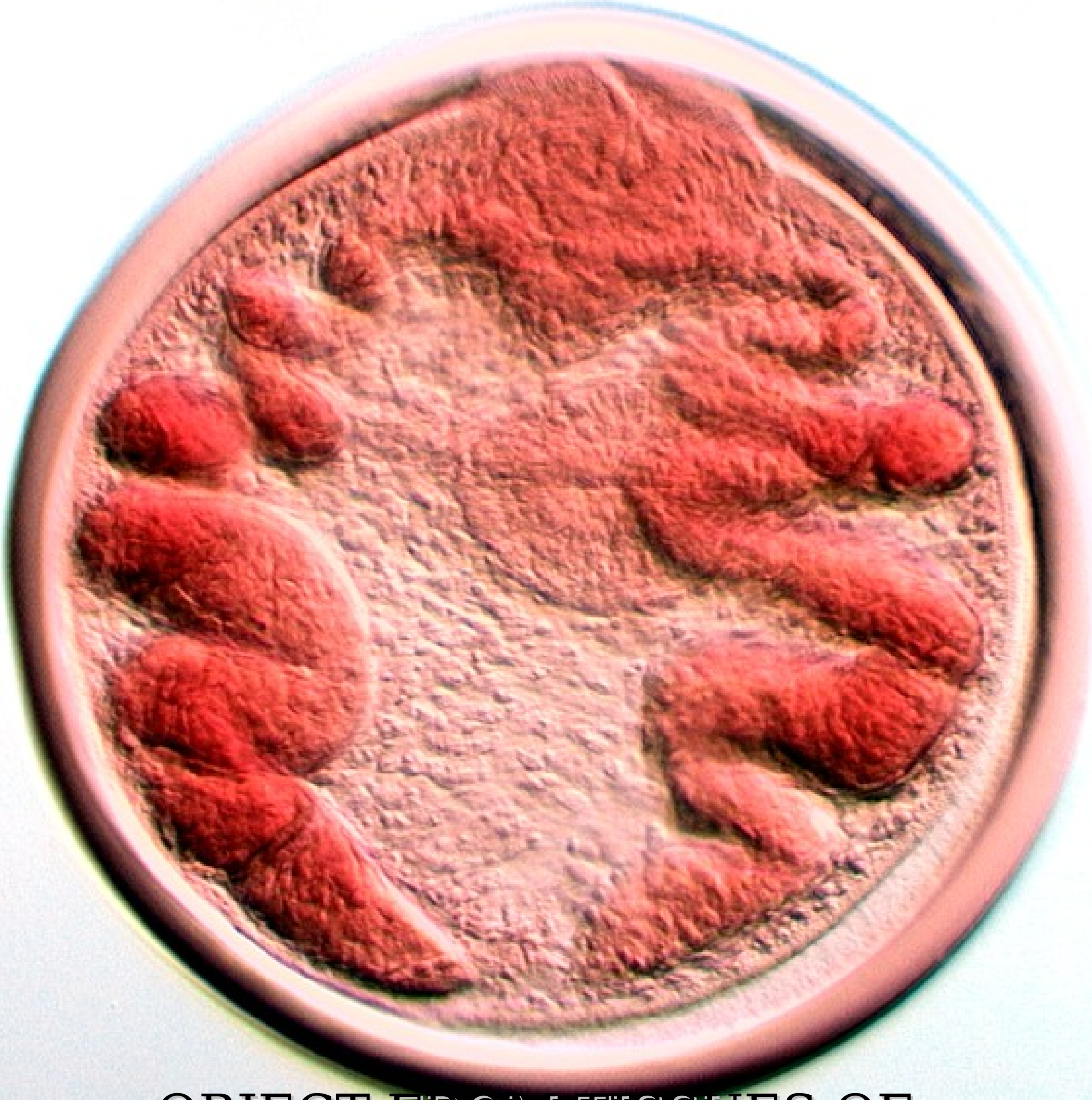
- elongate
- single genital pore
- < 14 lateral branches of uterus



SOIL SAMPLE

Rhabditiform first stage hookworm larva

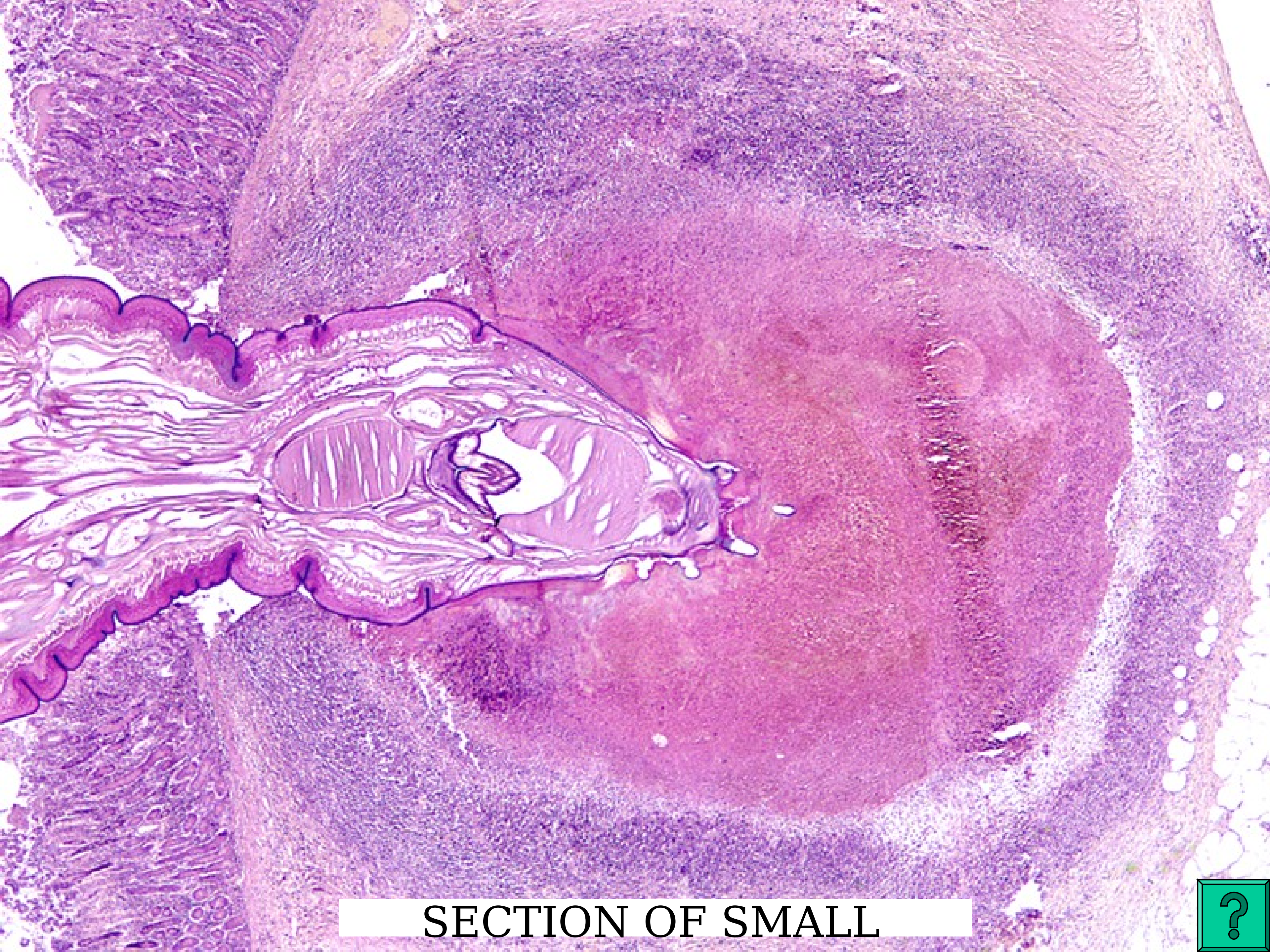
- corpus, isthmus, and end bulb in esophagus
- large buccal cavity (not visible here)



OBJECT FROM TISSUES OF

Paragonimus westermani metacercaria

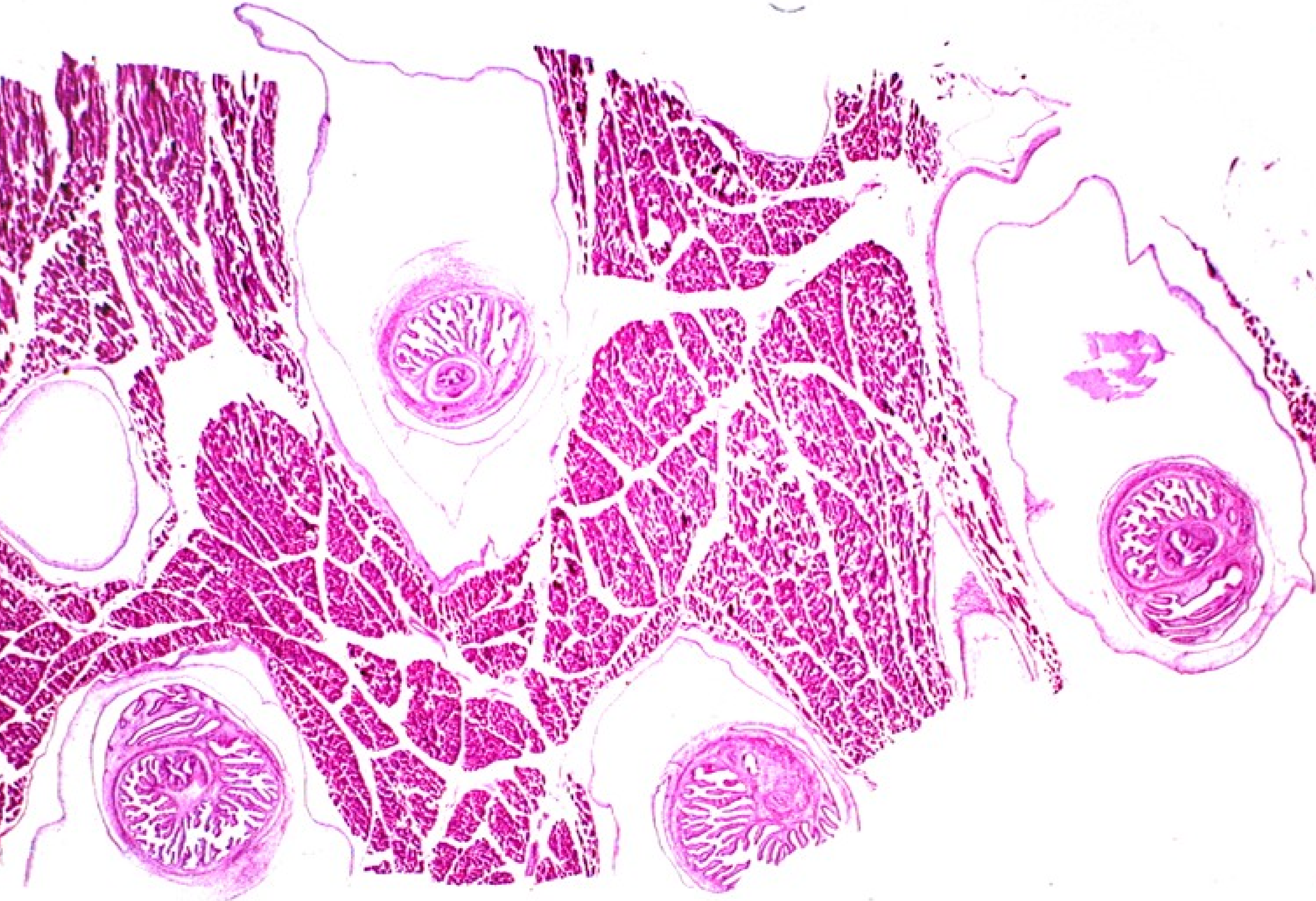
- round
- thick cyst wall
- acetabulum visible
- undulating intestinal ceca



SECTION OF SMALL

Macracanthorhynchus hirudinaceous

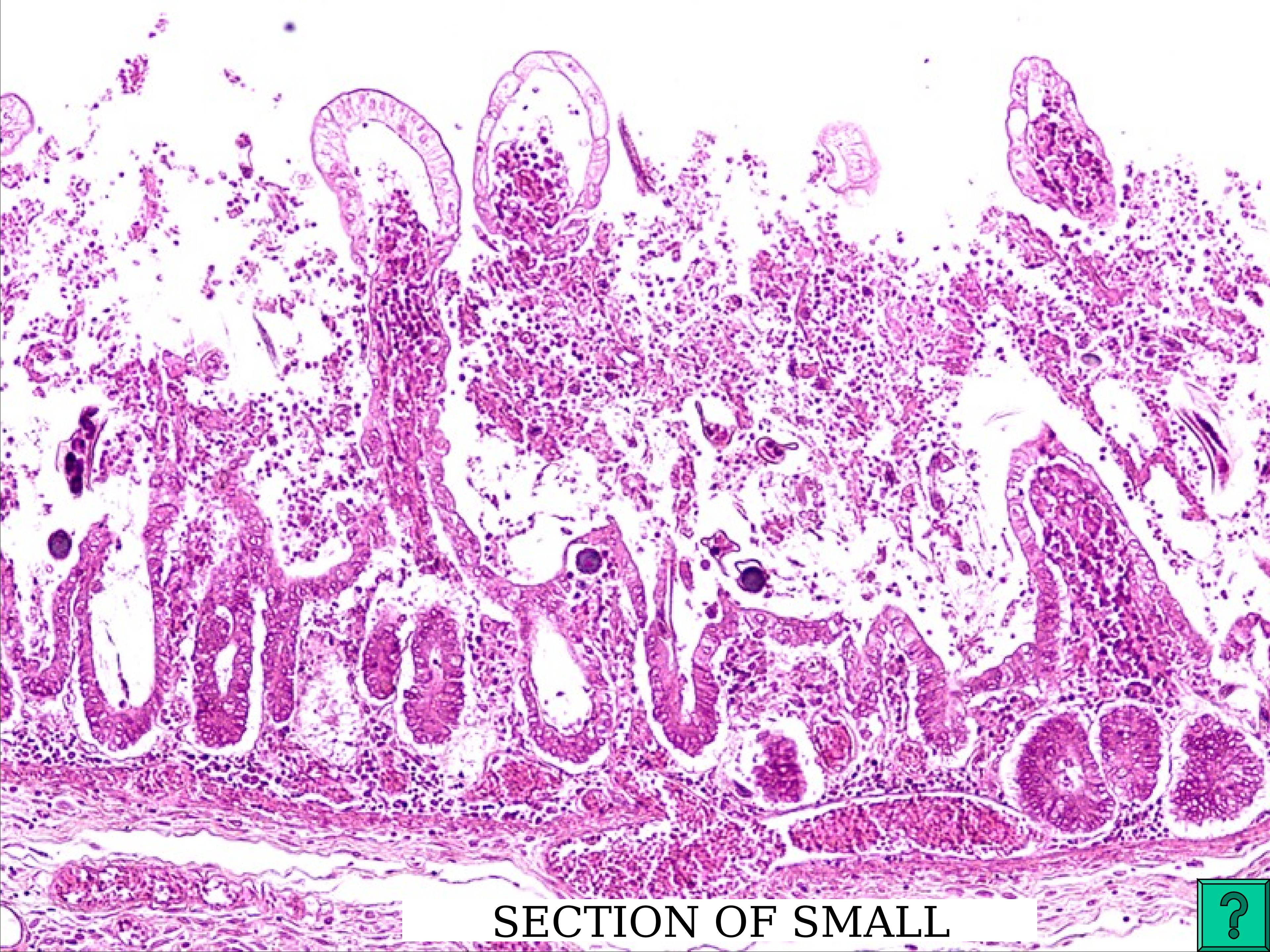
- proboscis with spines (at tip of proboscis)
- no digestive tract
- pseudocoelom



SECTION OF SKELETAL MUSCLE

Taenia solium cysticerci

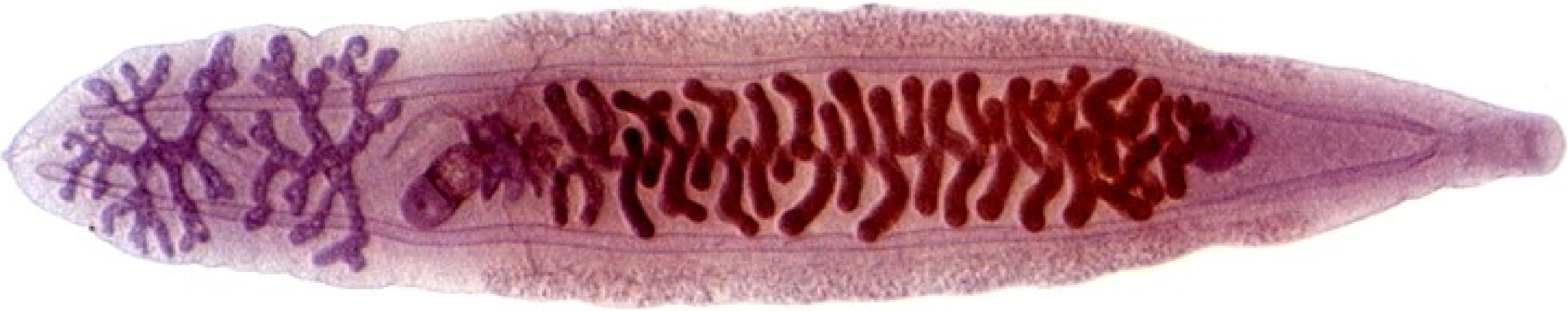
- scolex inside bladder
- absence of inflammation



SECTION OF SMALL

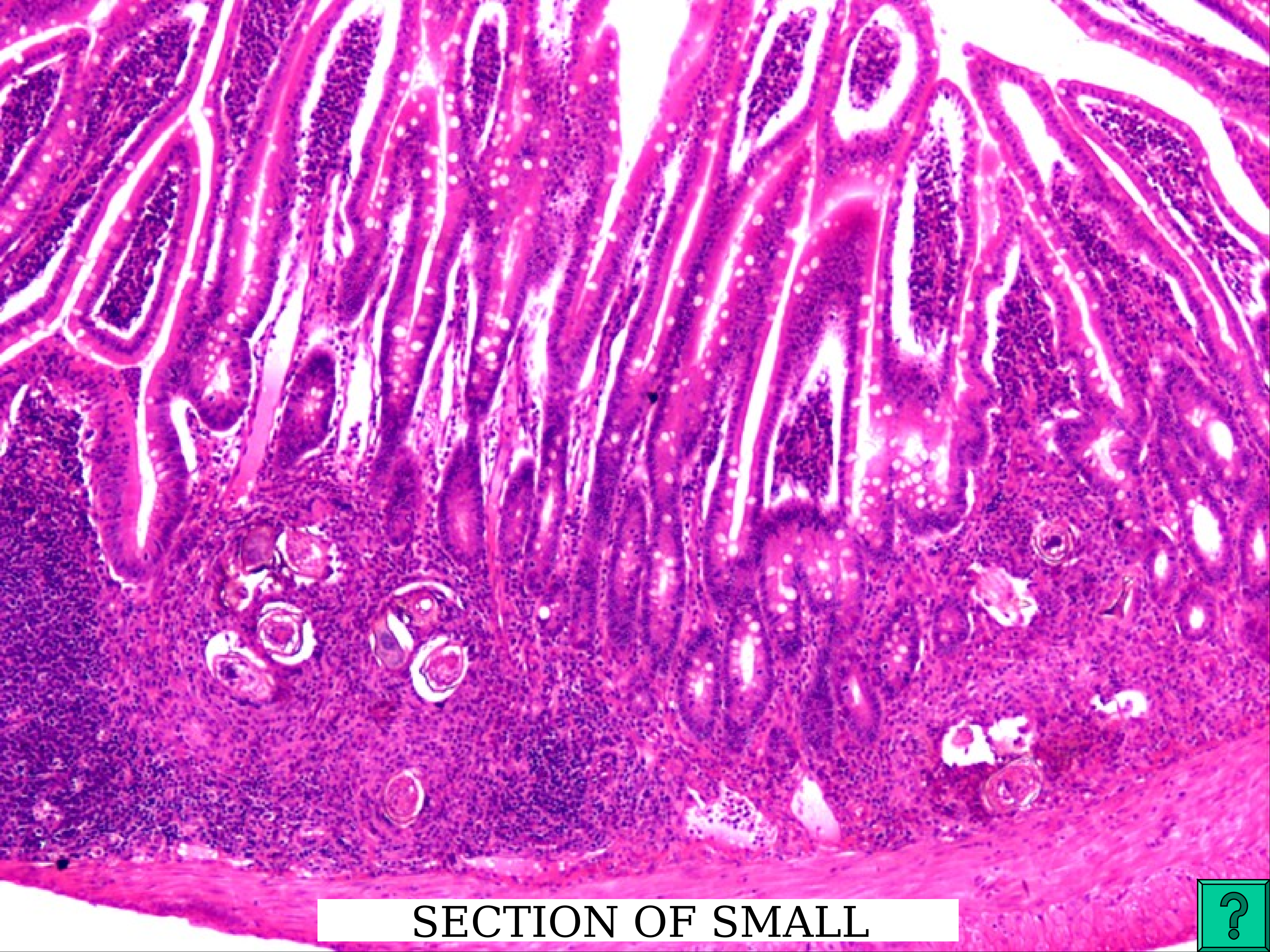
Strongyloides stercoralis

- numerous small nematodes invading mucosa



Clonorchis sinensis adult

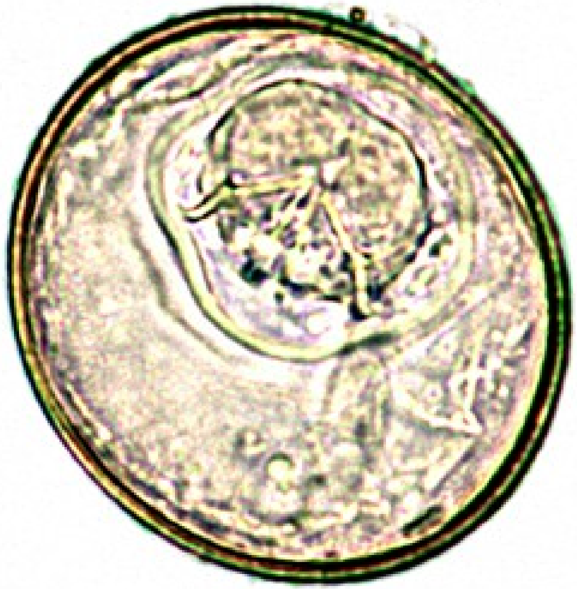
- elongate
- tandem, dendritic, posterior testes
- straight intestinal ceca, reaching posterior end
- prominent seminal receptacle



SECTION OF SMALL

Schistosoma mansoni eggs

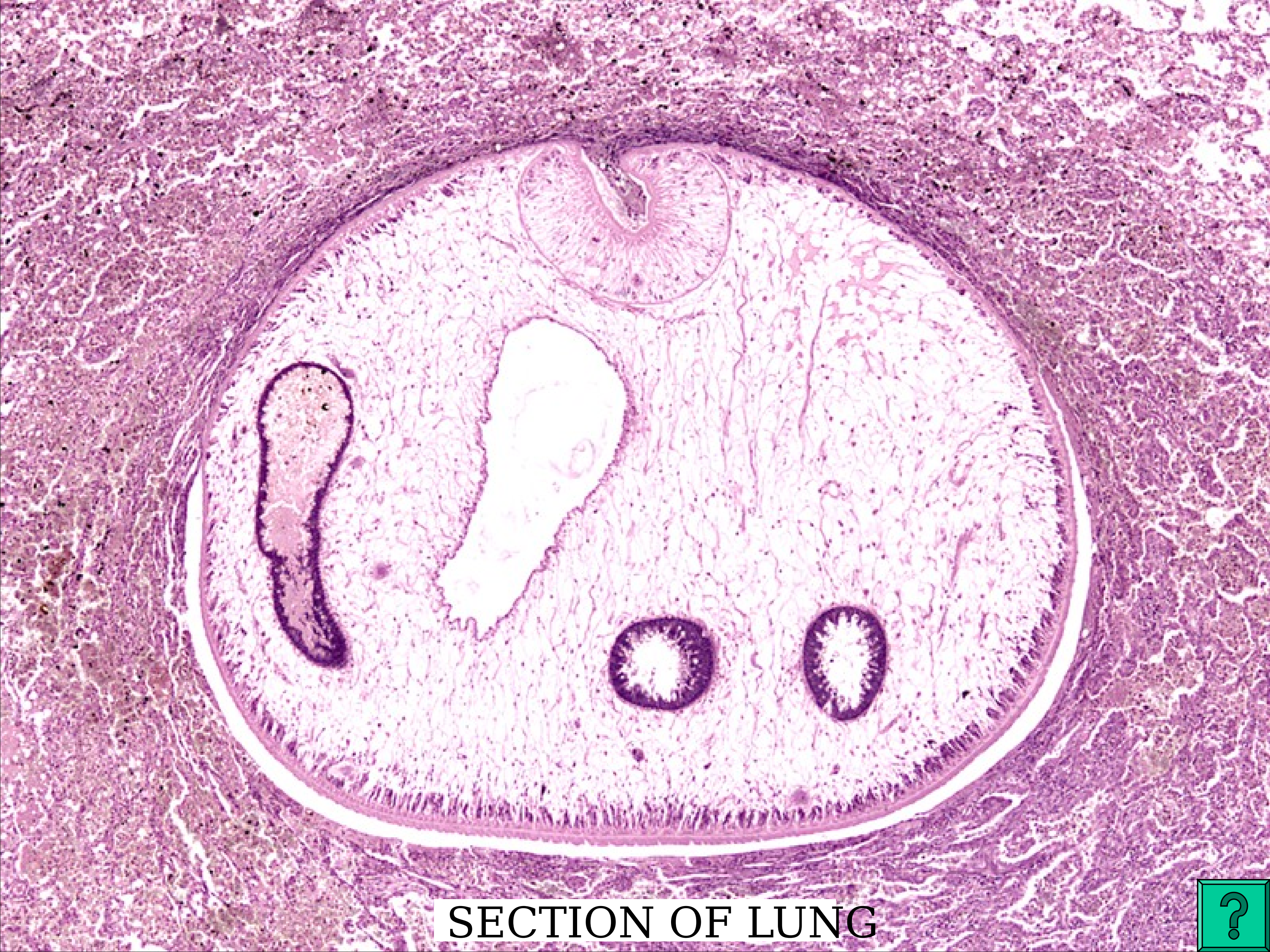
- elongate eggs in submucosa
- inflammatory reaction around eggs



FECAL SPECIMEN

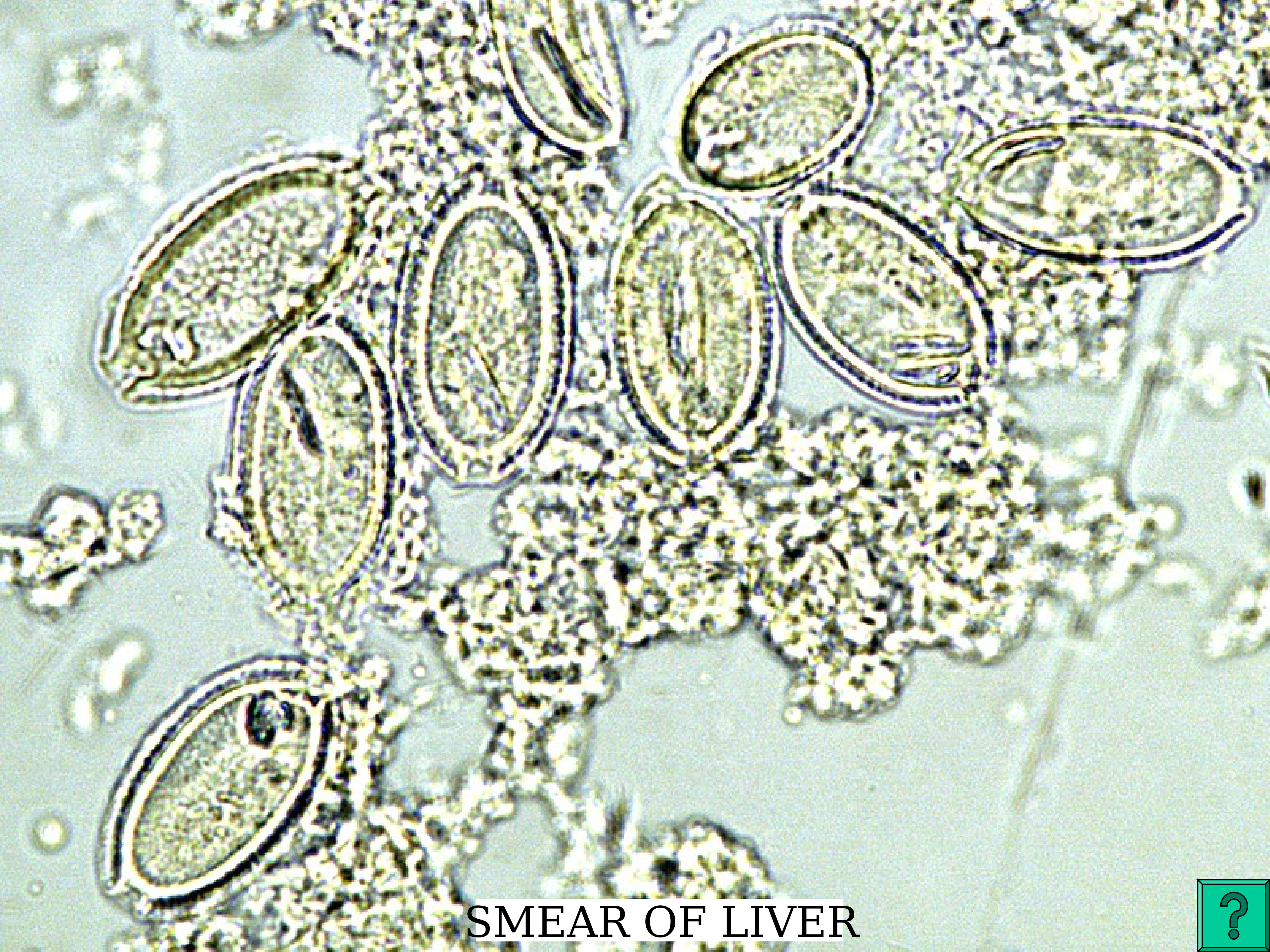
Hymenolepis diminuta egg

- medium to large size
- round to oval shape
- brown color
- oncosphere within embryophore
- embryophore lacks polar filaments
- surrounding gelatinous layer and capsule
- non operculate


SECTION OF LUNG

Adult *Paragonimus westermani*

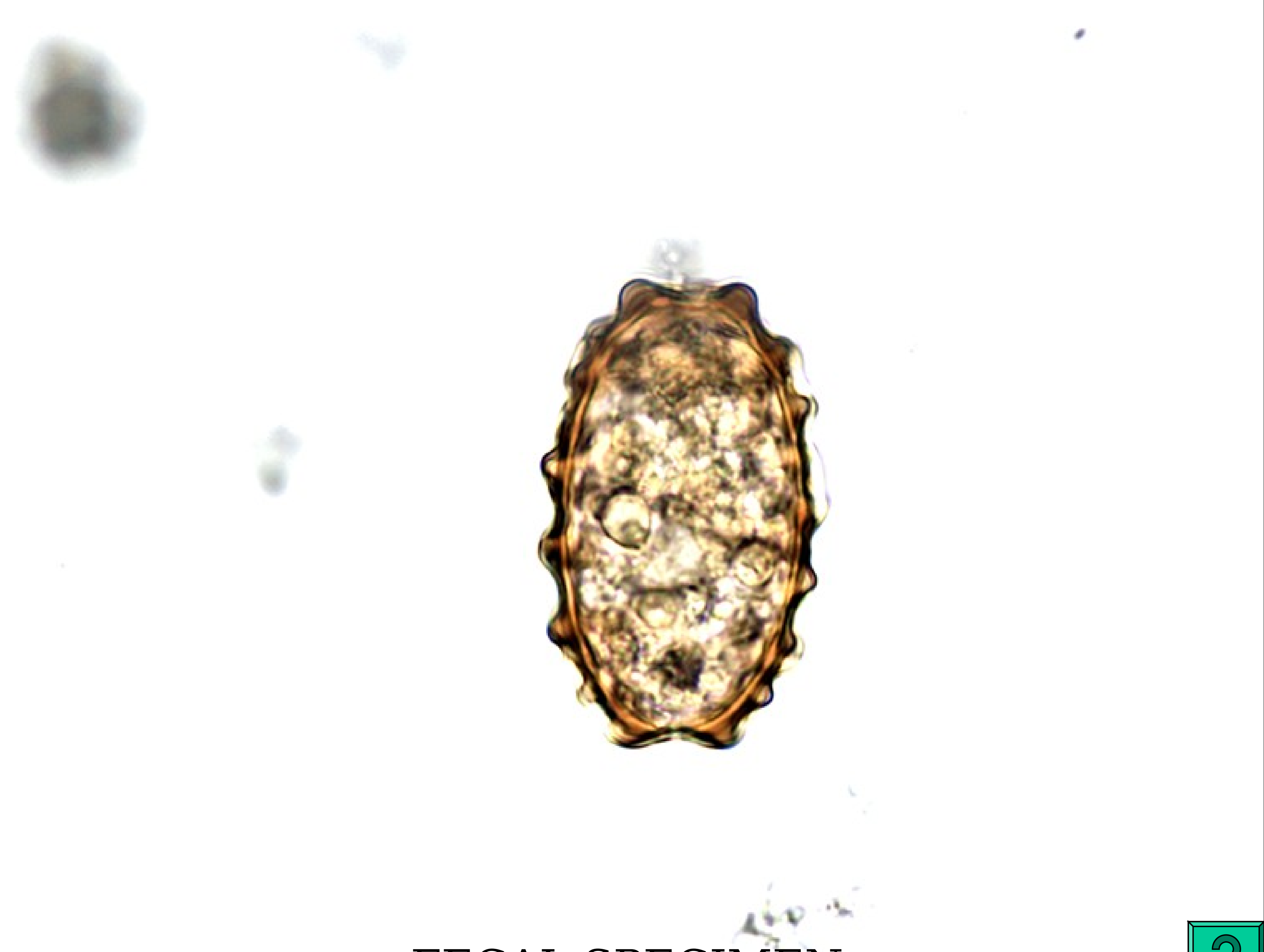
- acoelomate
- acetabulum
- 2 intestinal ceca



SMEAR OF LIVER

Capillaria hepatica eggs

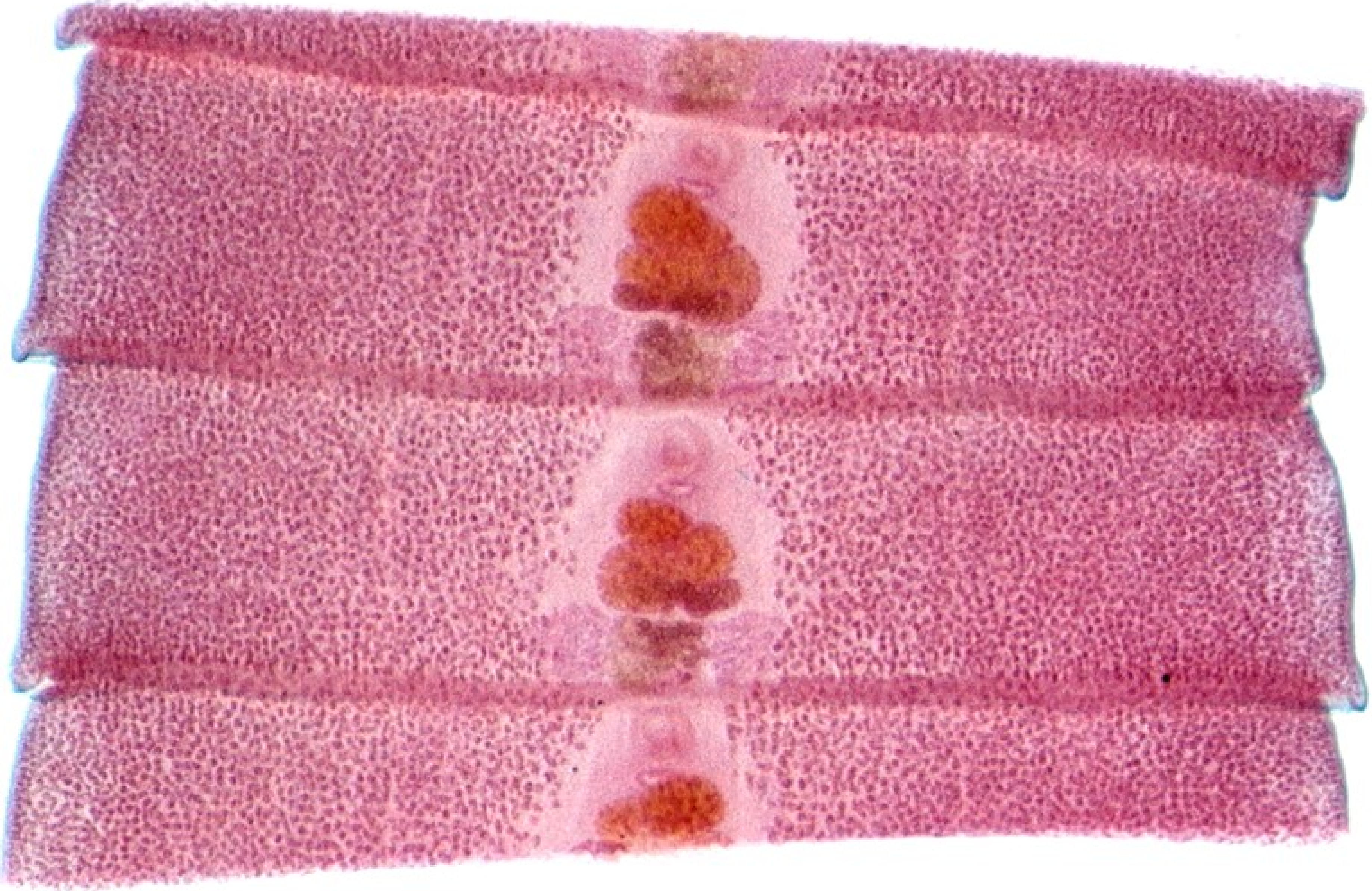
- barrel shape
- polar plugs
- pits in shell
- unembryonated
- non operculate



FECAL SPECIMEN

Ascaris lumbricoides unfertilized egg

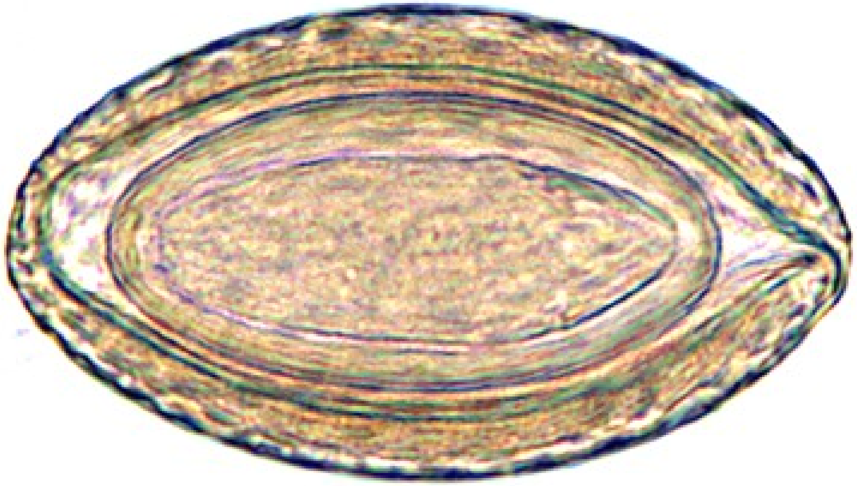
- elongate shape
- brown mammillated surface
- relatively thin shell
- disorganized contents, filling interior
- non operculate



FECAL SPECIMEN

Diphyllobothrium latum gravid proglottid

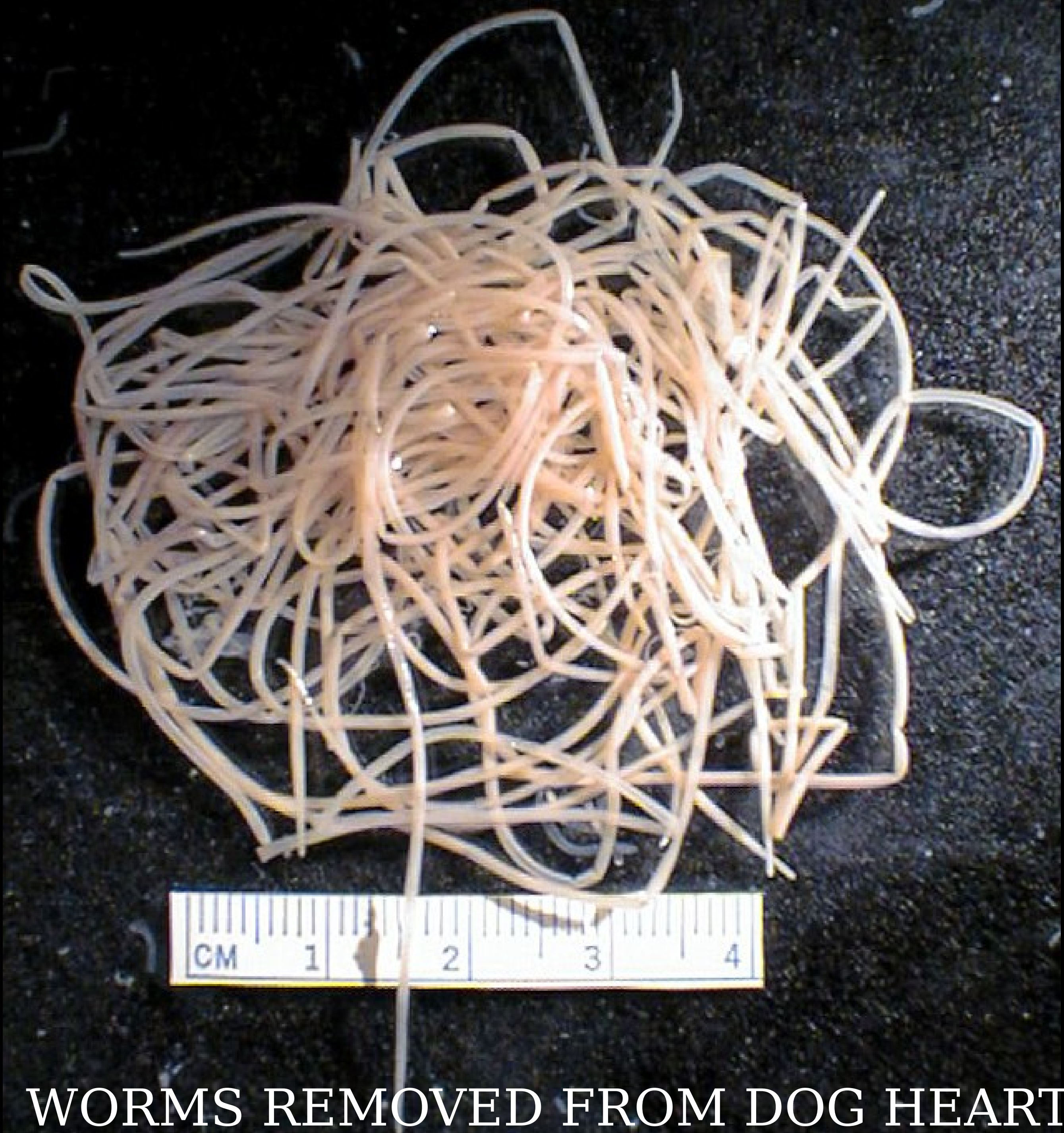
- wider than long
- follicular vitellaria
- bilobed ovary
- eggs released through uterine pore



FECAL SPECIMEN

Acanthocephalan egg

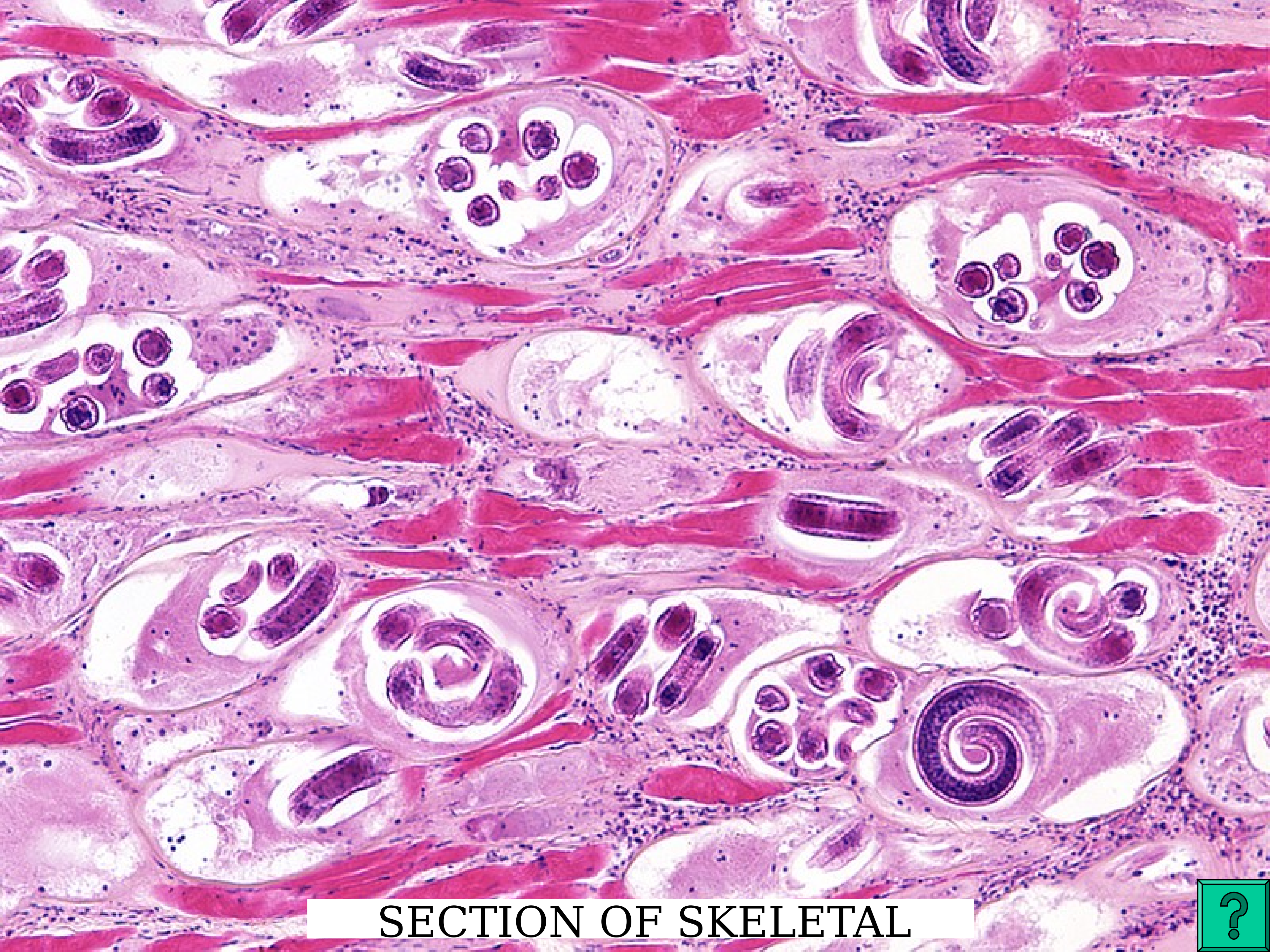
- medium size
- ellipsoid shape
- 3-layered egg shell
- contains acanthor larva
- non operculate



WORMS REMOVED FROM DOG HEART

Dirofilaria immitis adults

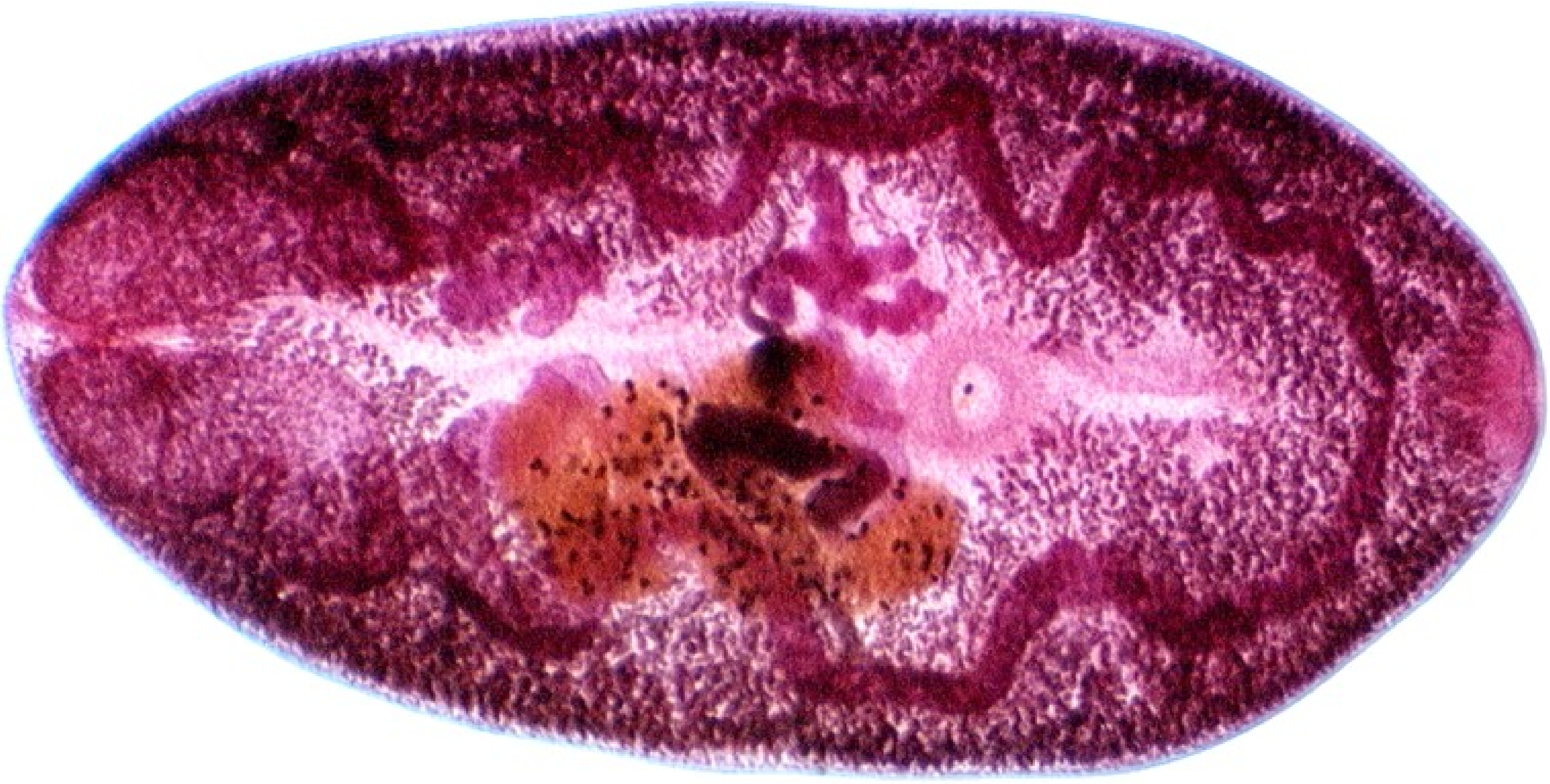
- long, threadlike nematodes



SECTION OF SKELETAL

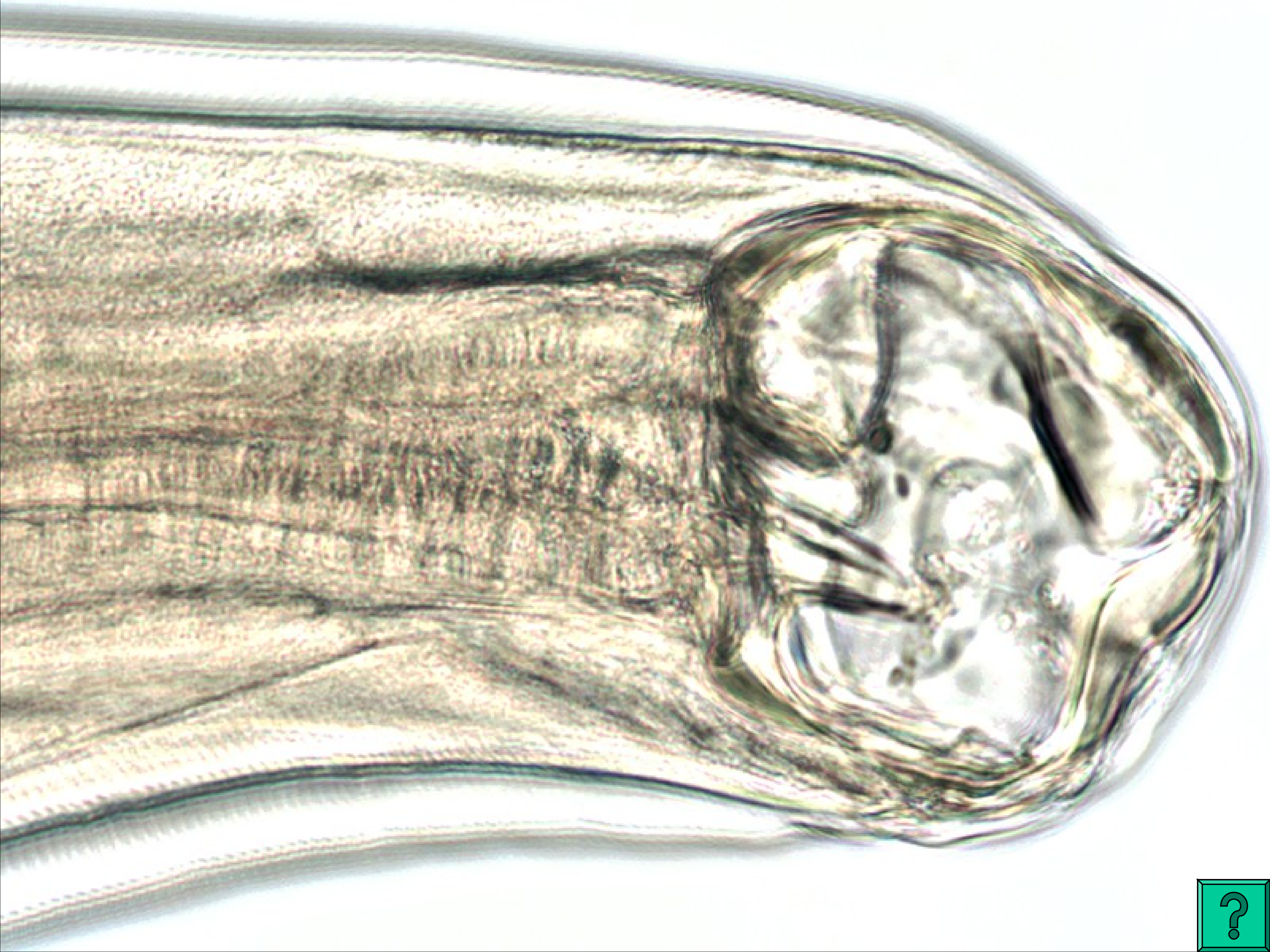
Trichinella spiralis larvae

- coiled nematode larvae within nurse cells



Paragonimus westermani adult

- coffee bean shape
- undulating intestinal ceca
- deeply lobate, para testes
- off-centered, lobed ovary



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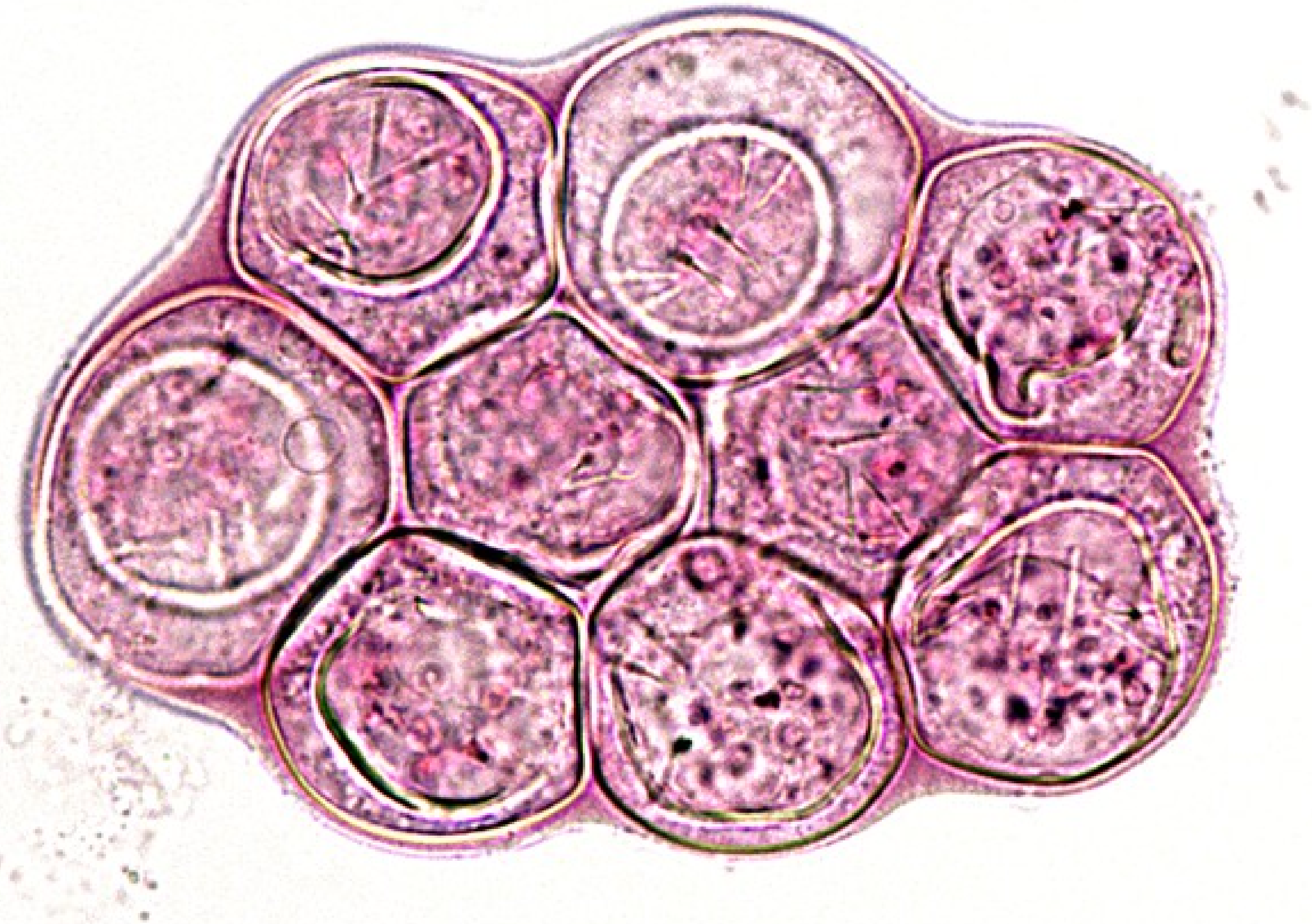
Necator americanus anterior end

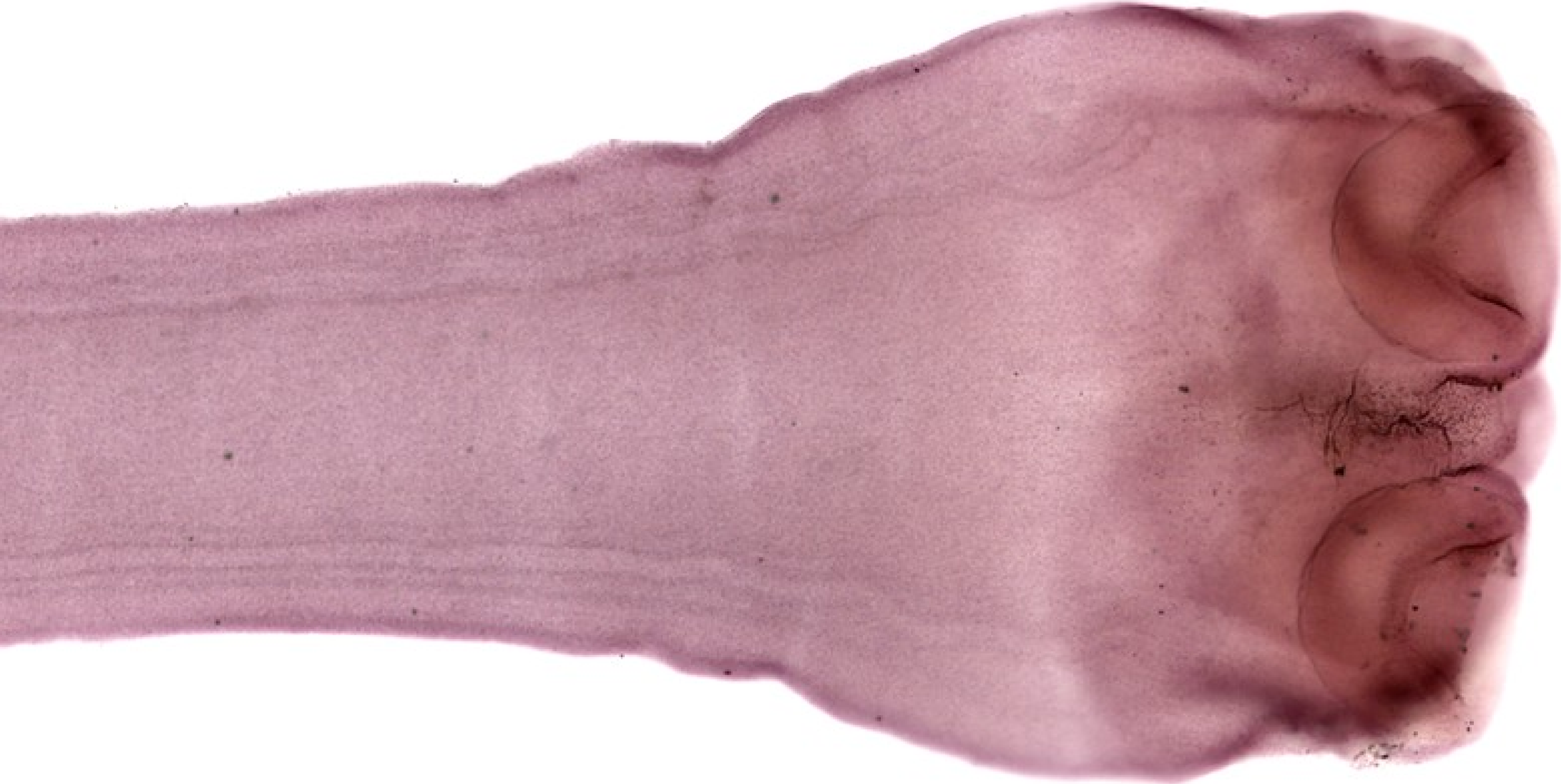
- ventral cutting plates in buccal cavity
- large dorsal cone



FECAL SPECIMEN

Dipylidium caninum eggs

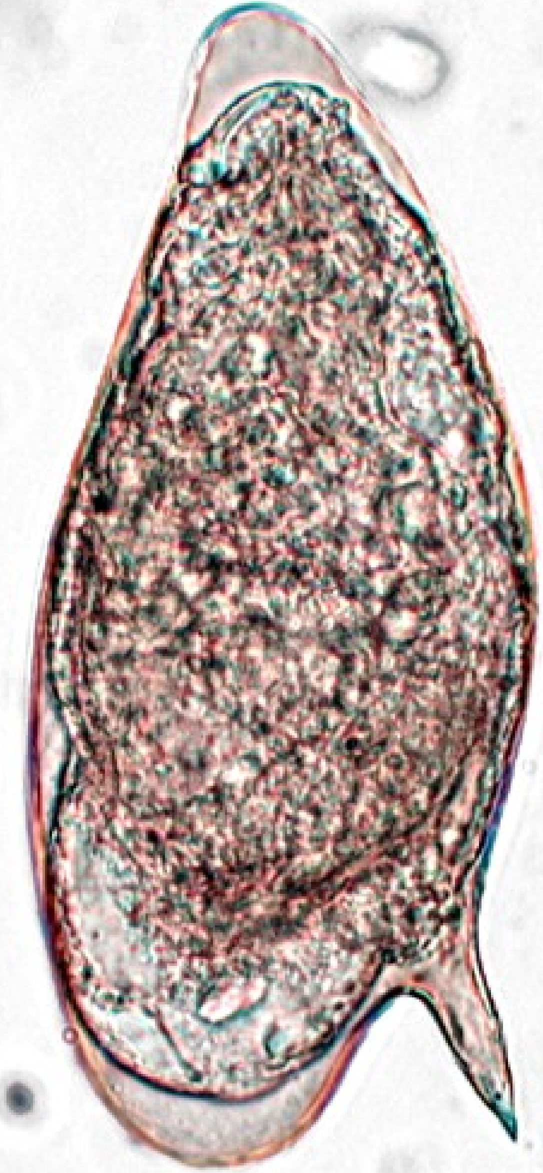
- light brown color (when unstained)
- contain hexacanth larva (oncosphere)
- eggs occur in packets
- non operculate



FECAL SPECIMEN

Taenia saginata scolex

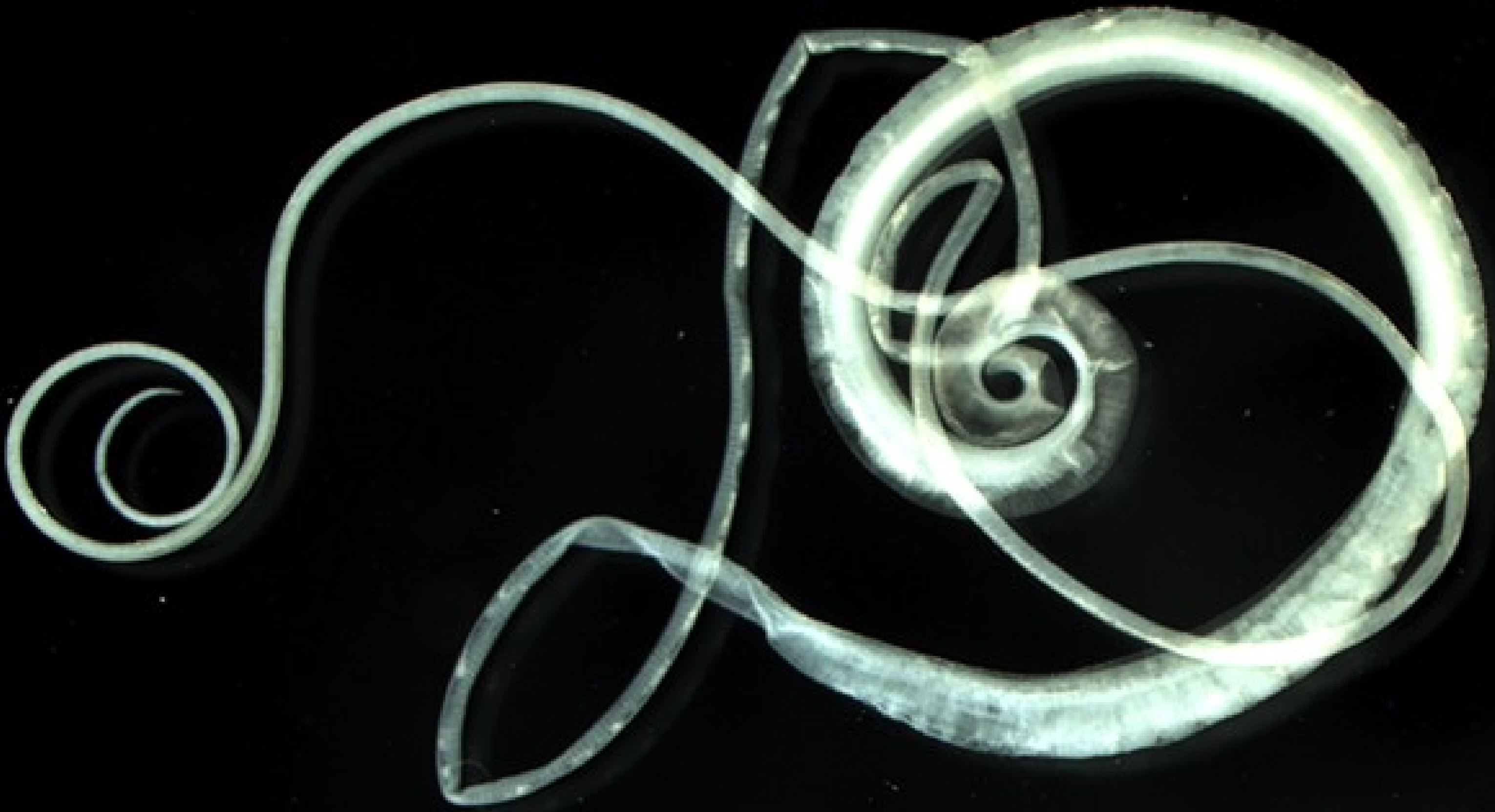
- 4 suckers
- no rostellum or hooks



FECAL SPECIMEN

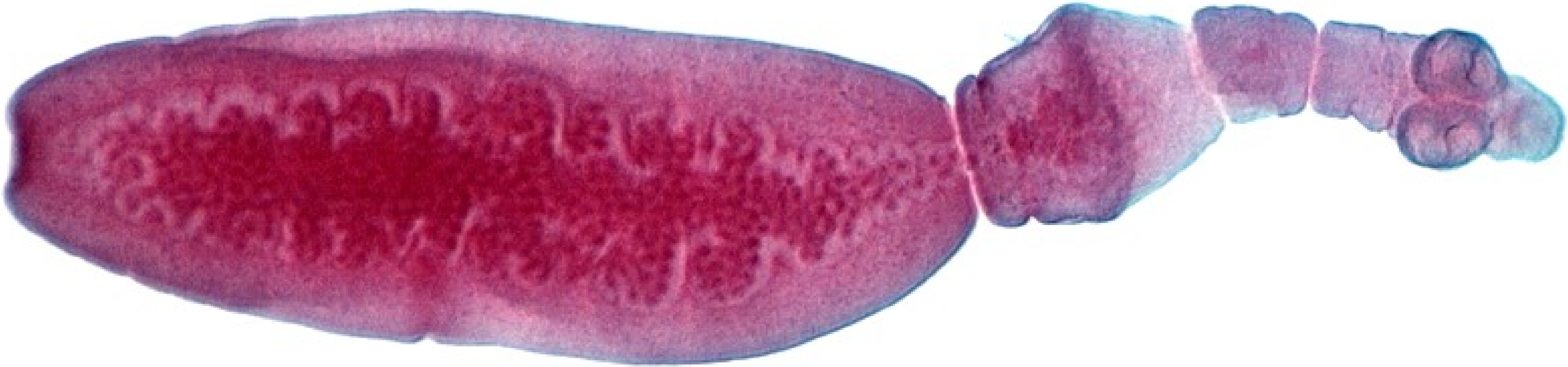
Schistosoma mansoni egg

- large size
- elongate
- yellow brown color
- contains miracidium
- prominent lateral spine
- non operculate



Trichuris trichiura adult male

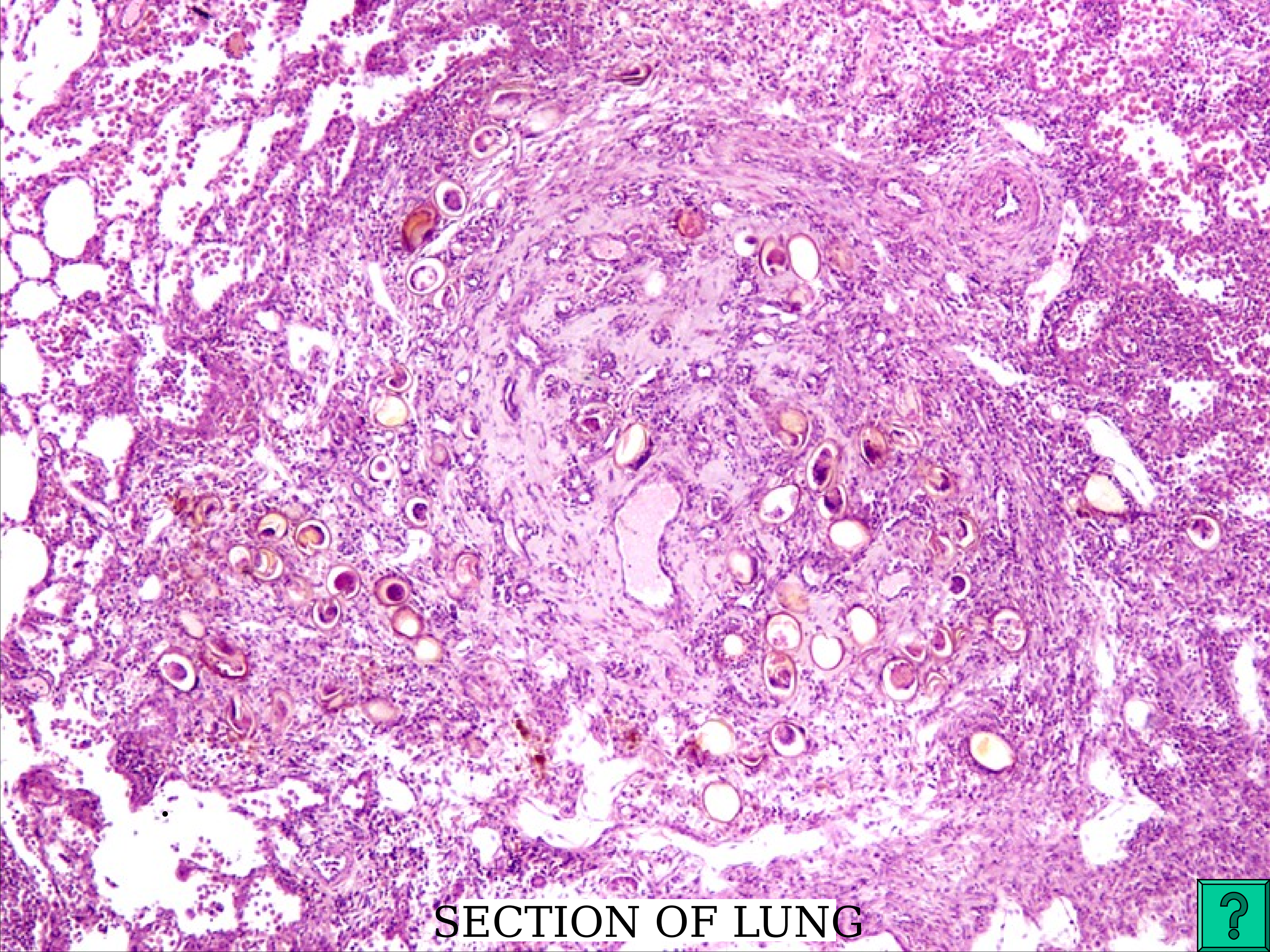
- long, thin anterior end
- whip-like shape
- curved posterior end (typical of male nematodes)



FECAL SPECIMEN FROM

Echinococcus granulosus adult

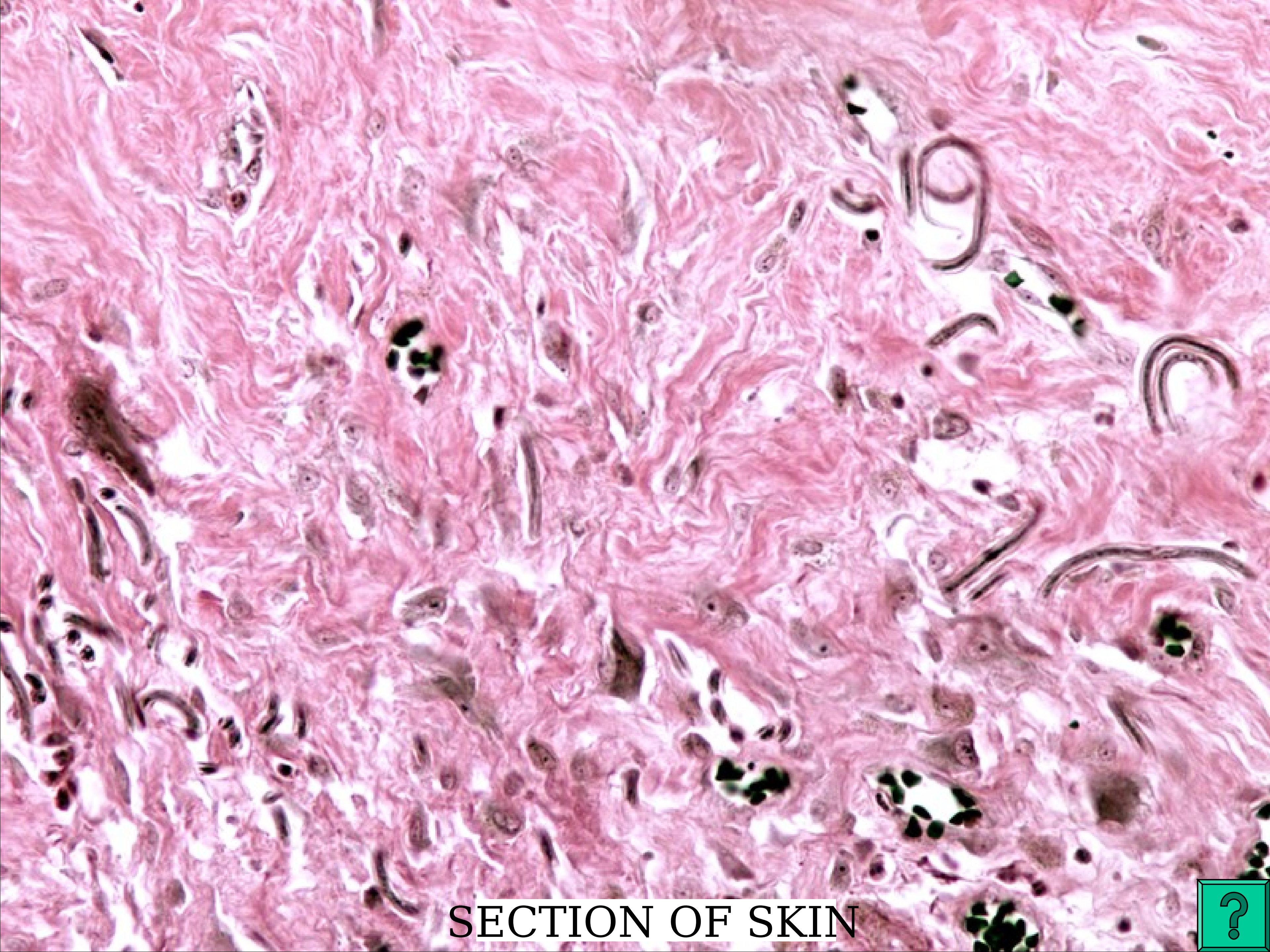
- only 3 proglottids, immature, mature, and gravid
- 4 suckers on scolex
- armed rostellum
- single, lateral, equatorial genital pore



SECTION OF LUNG

Paragonimus westermani eggs

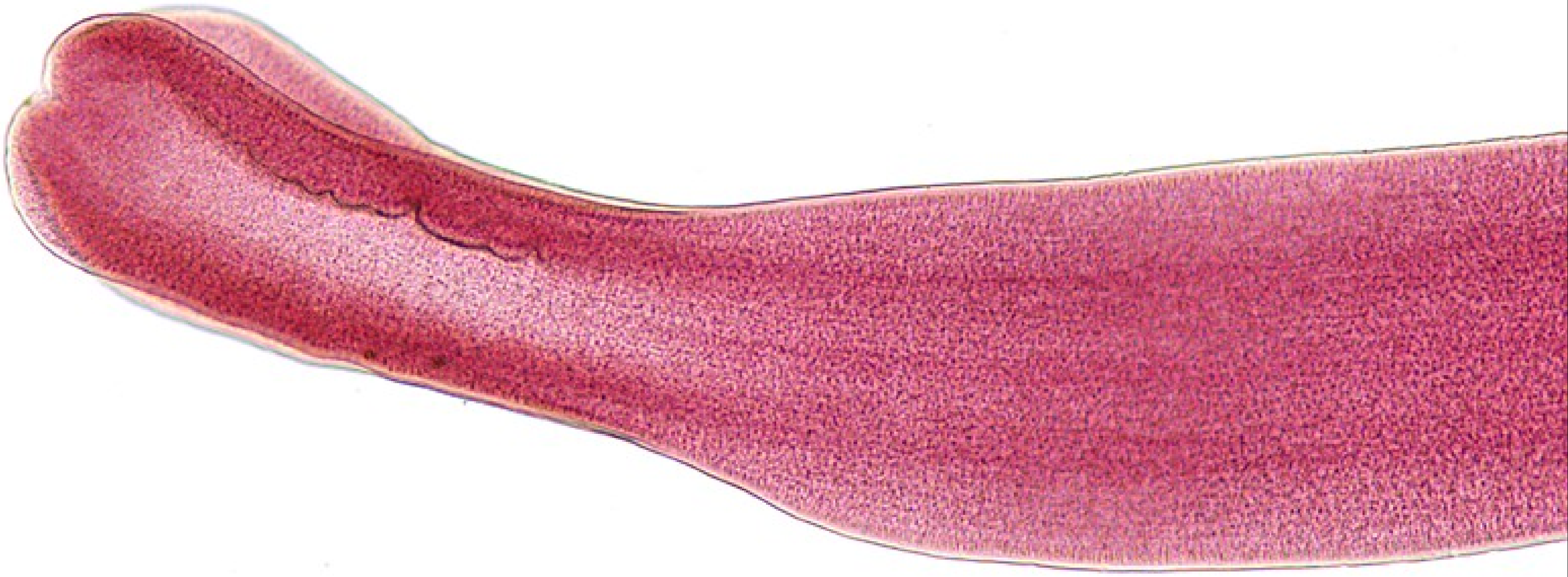
- numerous oval, unembryonated eggs
- large inflammatory response



SECTION OF SKIN

Onchocerca volvulus microfilariae

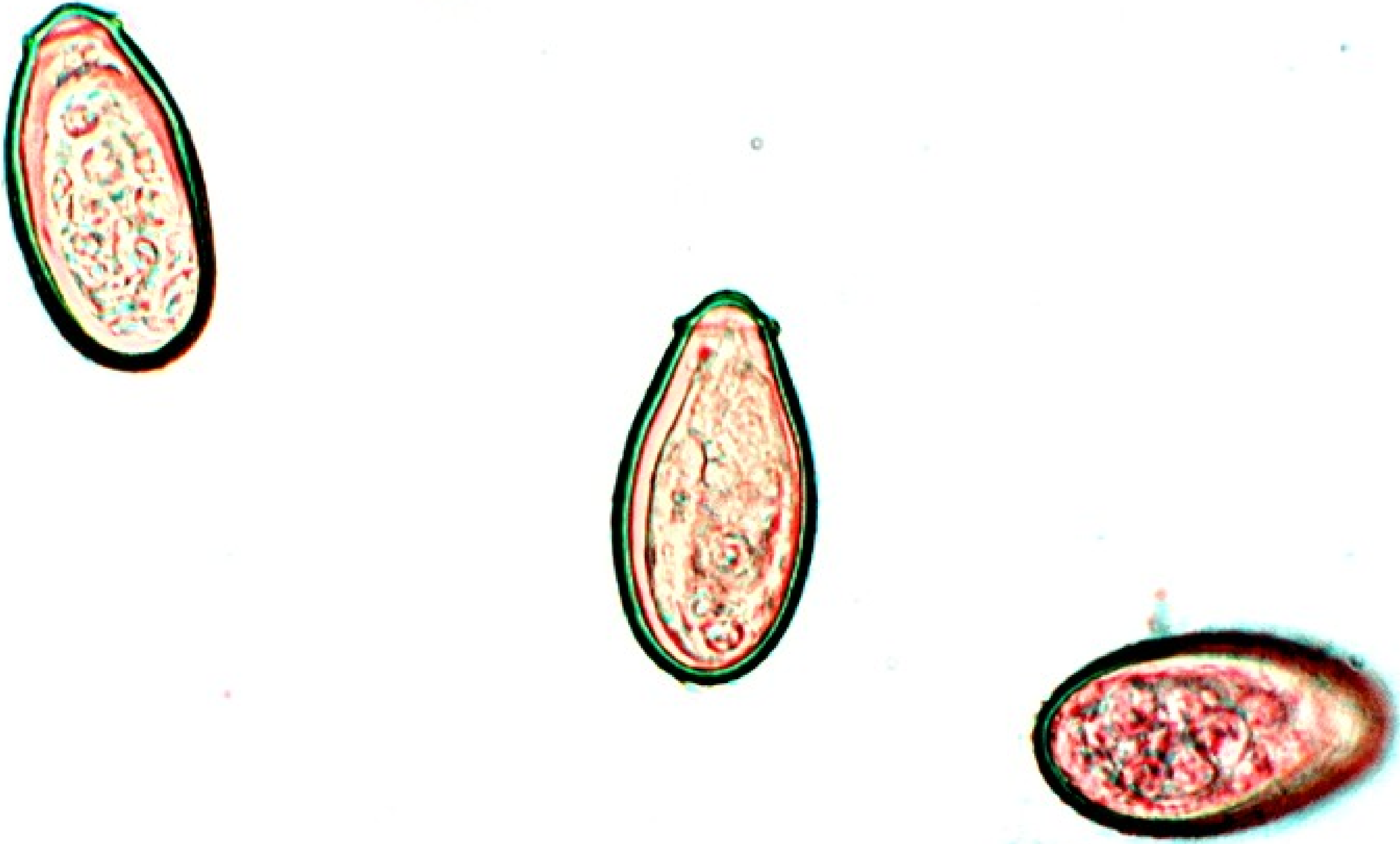
- microfilariae wandering in the dermis
- note: smaller microfilariae of *Mansonella* spp. may also be found in skin snips



FECAL SPECIMEN

Diphyllobothrium latum scolex

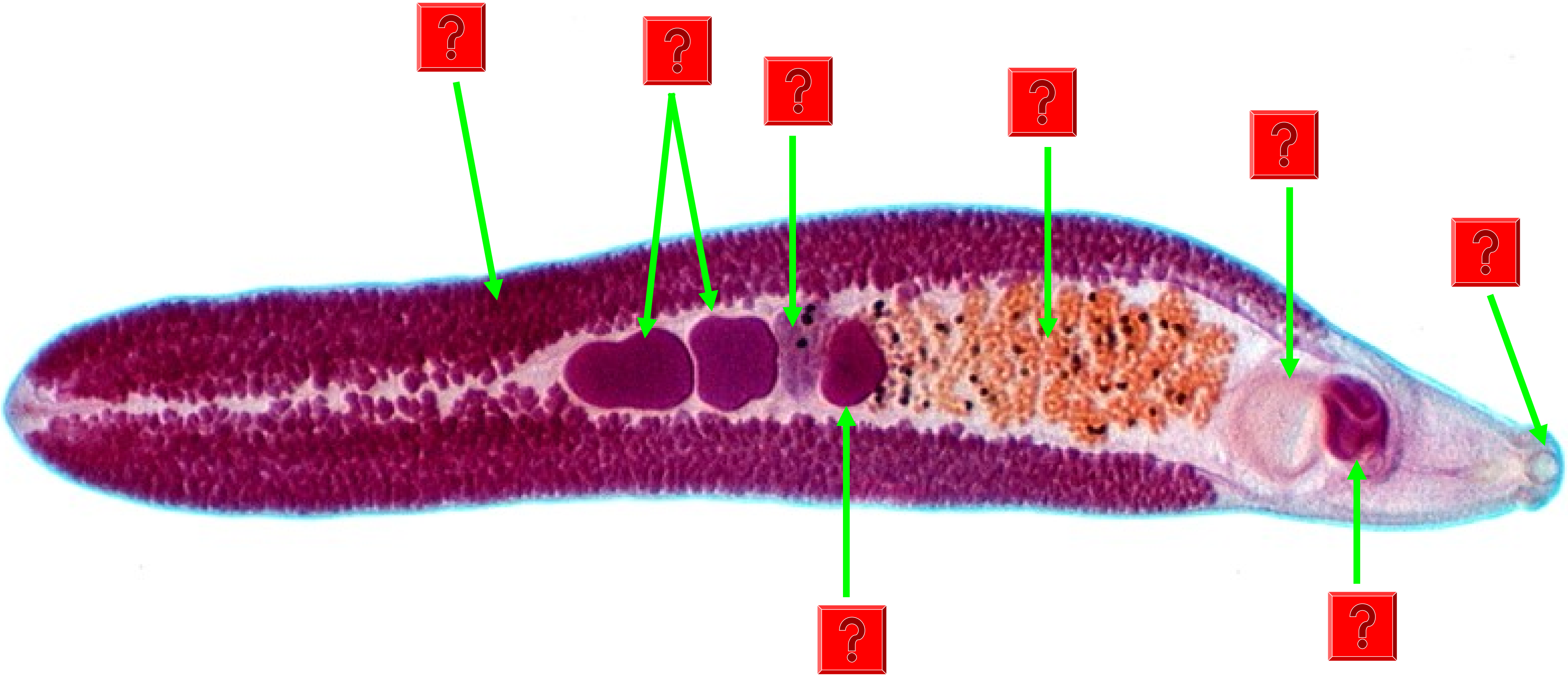
- solid body
- presence of slit-like bothria
- absence of suckers or hooks



FECAL SPECIMEN

Clonorchis sinensis eggs

- small size
- vase shaped
- yellow brown color
- contains miracidium
- prominent operculum in a rim
- small abopercular knob



?

Echinostoma revolutum adult

- collar surrounding mouth
- anterior acetabulum
- pretesticular ovary
- tandem testes

vitelline glands

testes

ootype

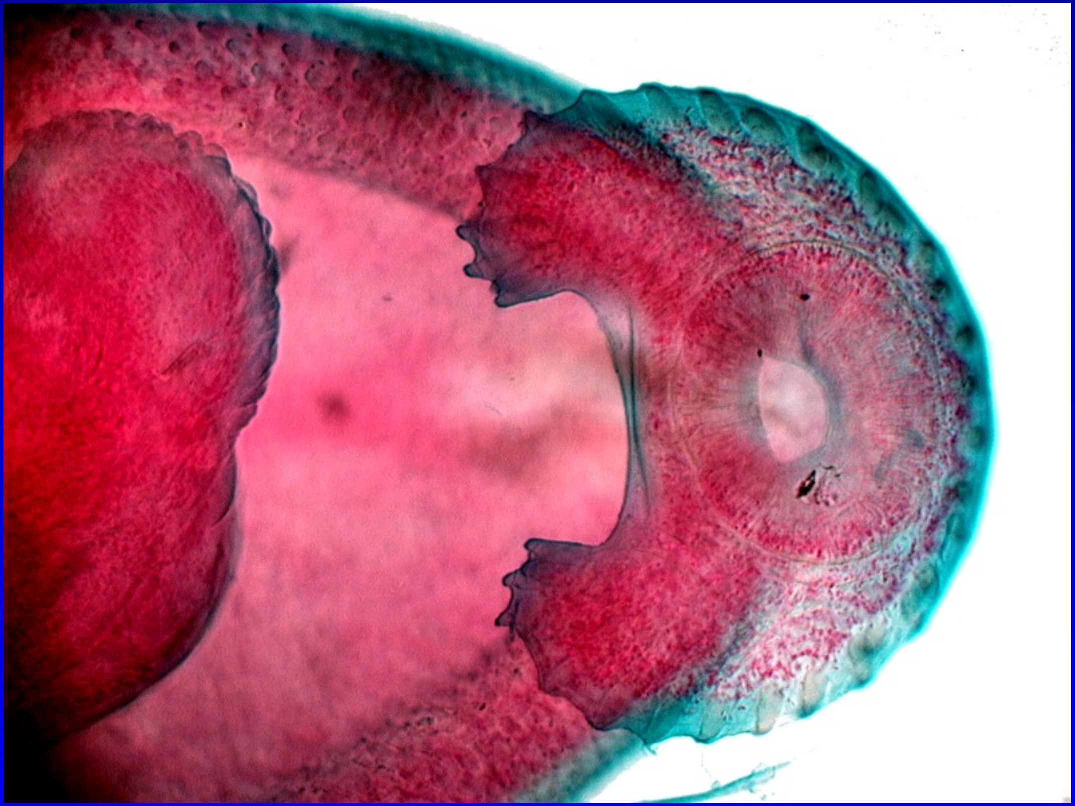
ovary

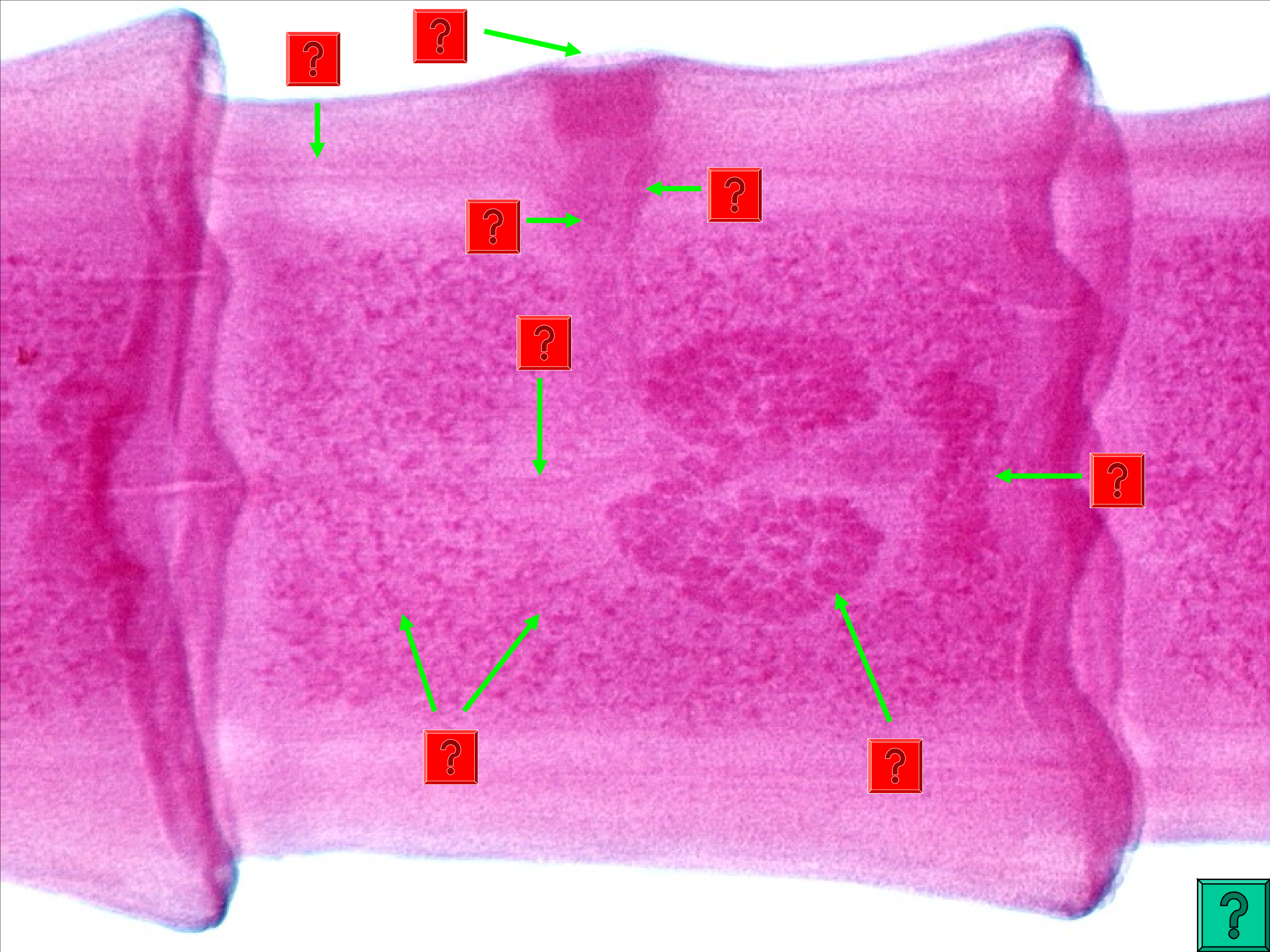
uterus

acetabulum

internal seminal vesicle

mouth with collar of spines





Mature taeniid proglottid

- vitelline gland in one mass
- follicular testes
- blind-ended uterus
- single, lateral genital pore
- bilobed ovary

uterus

ovary

collecting tubule

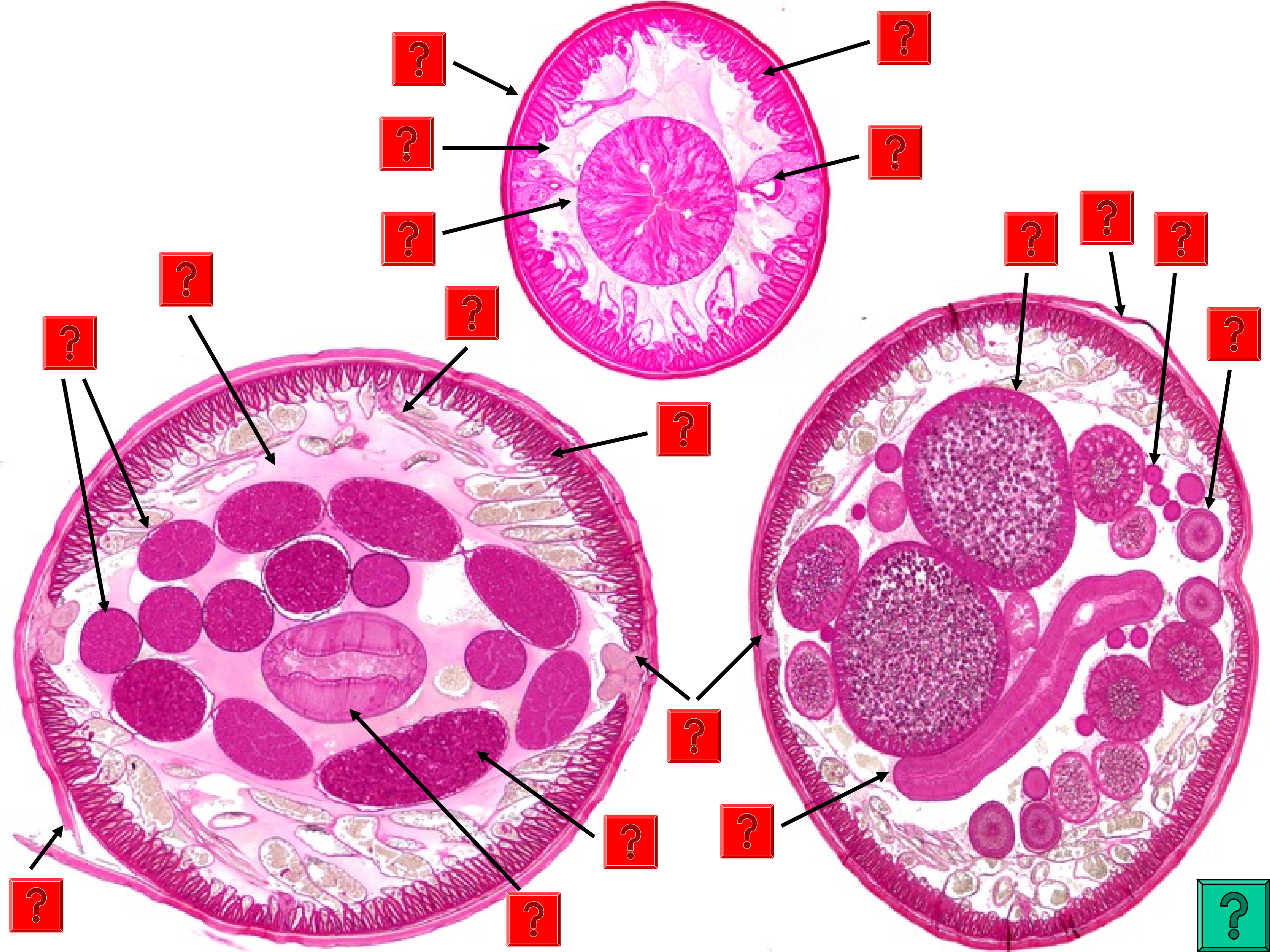
follicular testes

vitelline gland

vagina

vas deferens

genital pore



Nematode (*Ascaris lumbricoides*) adults, cross sections

- triradiate esophageal lumen
- cuticle
- pseudocoelom
- no circular muscles

pseudocoelom

esophagus

lateral hypodermal cord

longitudinal muscle fibers

cuticle

testis

vas deferens

intestine

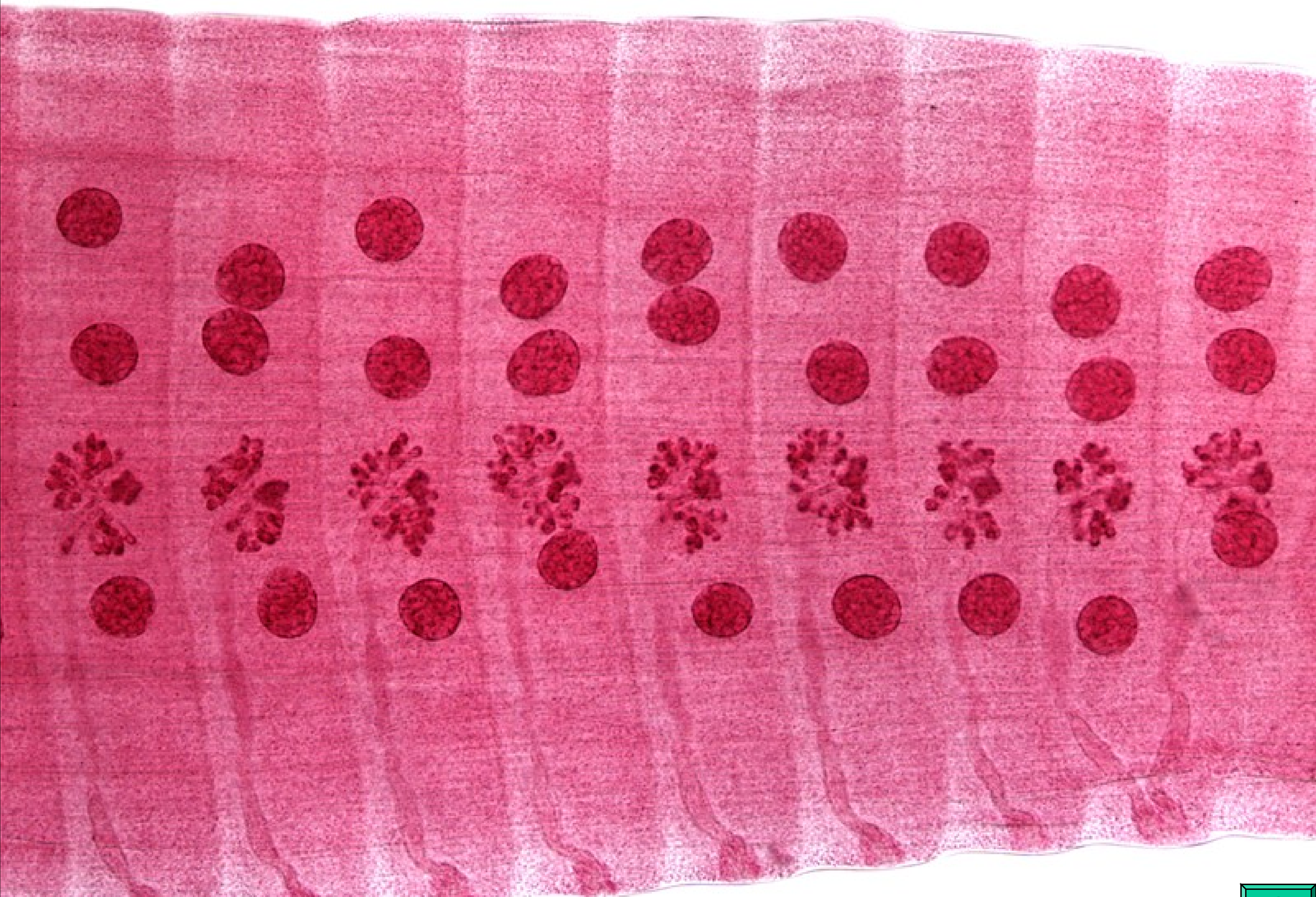
ovary

oviduct

uterus with eggs

excretory canal

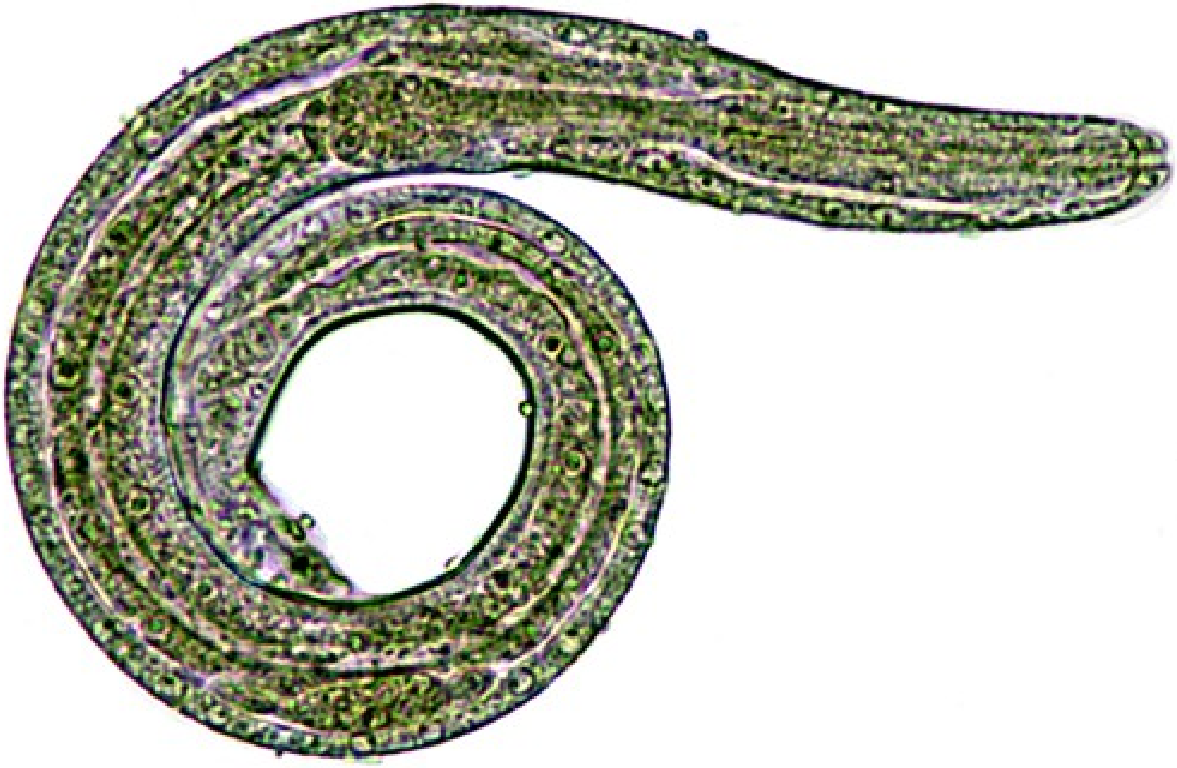
innervation process



?

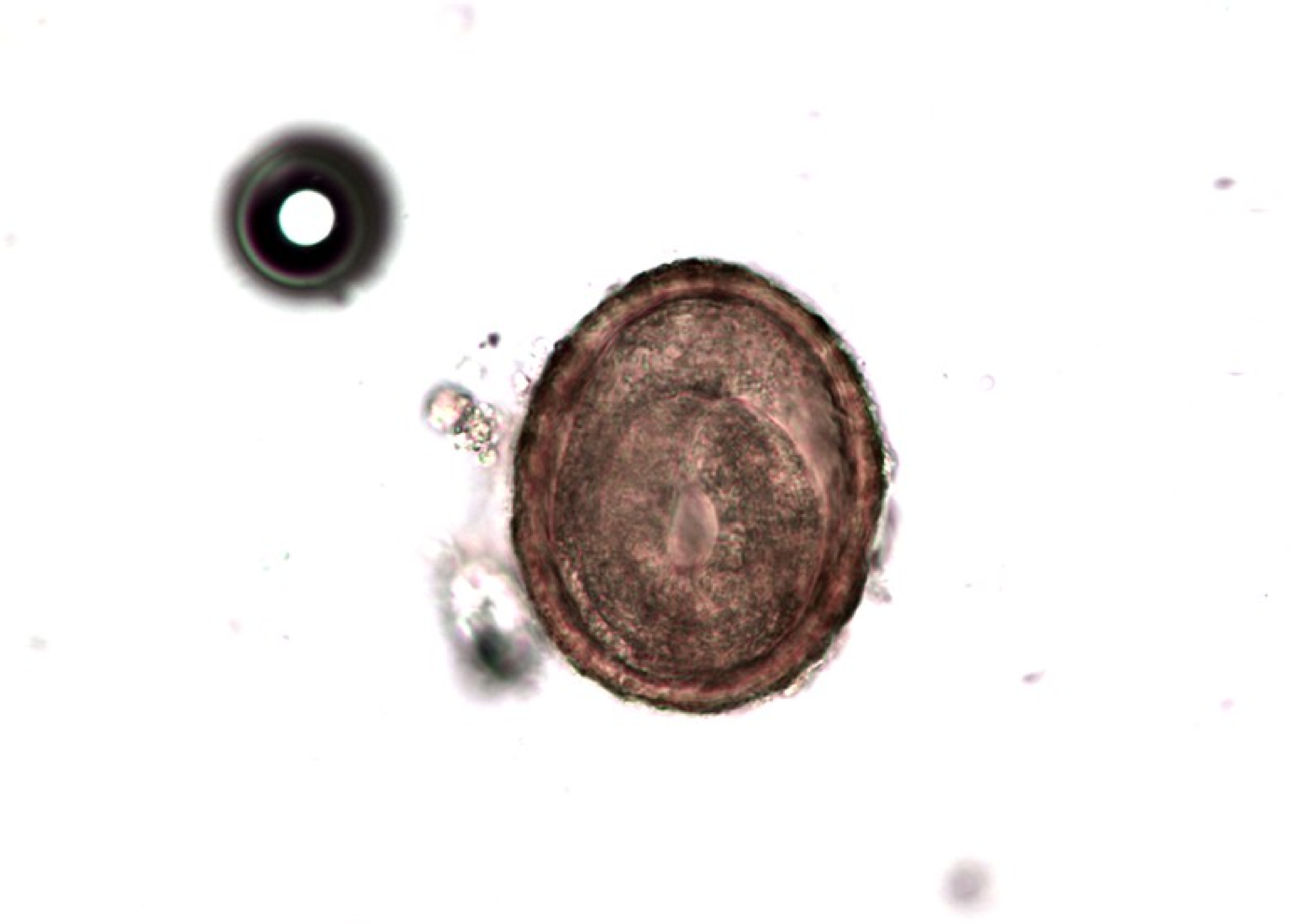
Hymenolepis diminuta mature proglottid

- three oval testes
- single lobate ovary
- short, wide segments



Rhabditiform (L_1) larva of *Strongyloides stercoralis*

- esophagus with corpus, isthmus, and end bulb
- prominent genital primordium
- short buccal cavity



SOIL
SAMPLE

Baylisascaris procyonis embryonated egg

- brown color
- thick walled
- rough surfaced

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Sources of Specimens

Source is listed by figure number. Where appropriate, catalogue numbers are provided. Unfortunately, some of these slides are no longer commercially available, and now exist only in teaching collections. **Abbreviations:** C, Carolina Biological Supply Co, Burlington, NC; M, Midwest Biological, Menomonee Falls, WI; S, Southern Biological Supply Co., McKenzie, TN; SD, Scientific Device Laboratory, Des Plaines, IL; T, Turtox (presently part of Ward’s); TR, Triarch, Ripon, WI; W, Ward’s Biology, Rochester, NY.

1.1 W: 92W4354

1.2 W: 92W4330

1.3 W: 92W4355

1.4 W: 92W6592

1.5 Source unknown

1.6 W: 92W4304

1.7 W: 92W4303

1.8 W: 92W4301

1.9 Collected by Mr. Greg Coussoulis

1.10 W: M975a

1.11 W: 92W4253

1.12 W: 92W4255

1.13 Collected by Mr. Brian Ostrander

2.1 W: 92W4213; SD: 4901

2.2 W: 92W4214; SD: 4923

2.3 W: 92W4235; Clinical specimen

2.4 W: 92W4235; C: PS 220; SD: 4919

2.5 W: 92W4043; SD: 4916

2.6 W: 92W4273; T: P1.245; SD: 4928

2.7 W: 92W4273

3.1 W: 92W4083; T: P1.11 & PS 180; Clinical specimen

3.2 W: 92W4084 ; C: Z115; Clinical specimen

3.3 W: 92W4063; Clinical

3.4 W: 92W4064 & M913; Clinical specimen

3.5 W: 92W4103 & M920; SD: 4912

3.6 W: 92W4104; SD 4912

3.7 W: 92W4123; SD: 4931

3.8 W: 92W4124; SD: 4931

3.9 C: P1.19; SD: 4929

3.10 W: 92W4132

3.11 W: 92W4128 & 92W4129

3.12 C: PS1100

3.13 W: 92W4444

3.14 W: 92W4445 & 92W4086

4.2 Specimen provided by AFIP Registry of Veterinary Pathology

4.3 Specimen provided by Dr. Sam R. Telford III

4.4 Specimen provided by Dr. Sam R. Telford III; SD: 378-999

4.5 W: 92W4839 & 92W4836

4.6 W: 92W4841

4.7 W: 92W4837

4.8 W: 92W4811 & T: H8.123; TR: ZA3-2

4.9 Specimen collected by author

4.10 W: 92W4855; C: PH1228

5.3 C: Z370

5.4 Histological specimen provided by Dr. William E. Collins; W: 92W4686

5.5 M: A177; S: Z212; W: 92W4660 & M1037

5.6 M: A177; W: 92W4660; clinical specimen, source unknown

5.7 Clinical specimen, source unknown

5.8 S: Z209

5.9 S: Z209

5.10 Clinical specimen, source unknown

5.11 & 5.12 C: Z363

5.13 W: M1036

5.14 W: M1036

5.15 W: M1036; C: Z363 & Z370

5.16 W: 92W4572; T: P1.455

6.1 W: 92W4940

6.2 W: 92W4985

6.3 W: 92W4970

6.4 C: PS1230

6.5 C: PS1210

6.6 W: 92W4930

6.7 C: PS1414

6.8 W: 92W5152

6.9 C: PS1218

6.10 C: PS1260

6.11 C: PS1415

6.12 W: 92W5123

6.13 C: PS1301

6.14 C: PS1310

6.15 Specimen provided by Dr. Eric S. Loker

6.16a C: PS1461; 6.16b W: 92W4958; 6.16c W: 92W5008; 6.16d Experimental infection

6.17a TR: ZD5-421; 6.17b C: PS1310; 6.17c-j Experimental infection

6.18 Snails provided by Dr. Fred Lewis

6.19 Specimen provided by Dr. William F. Font

6.20 W: 92W4909 & 92W4960

6.21 W: 92W5009; T: P5.177

6.22 C: PS1308

6.24 Clinical specimen, source unknown

7.1a C: PS1605; 7.1b-d W: 92W5300

7.2 W: 92W5400

7.3 W: 92W5400; C: PS1800

7.4a W: 92W5435; 7.4b Specimen provided by Harold W. Manter Laboratory of Parasitology, Univ. of Nebraska State Museum; 7.4c T: P5.2516; 7.4d W: 92W5452

7.5a W: 92W5463; 7.5b W: 92W5462

7.6 W: 92W5320

7.7a-c W: no cat. #; 7.7d W: 92W5323

Robert L. Rausch and Dr. Judy Sakanari; 7.8d Specimen provided by Harold W. Manter Laboratory of Parasitology, Univ. of Nebraska State Museum

7.9 C: PS1740; W: 92W5360

7.10 W: 92W5362 & 92W5340

7.11 W: 92W5300

7.12 W: 92W5257

7.13 W: 92W5361

8.1 W: 92W5790 & 92W5791

8.2a-c W: 92W5770; 8.2d Specimen provided by Academy of Health Sciences, Ft. Sam

8.4a W: 92W5741; 8.4b W: no cat. #; 8.4c-f Specimens courtesy of Dr. James B. Lok, Univ. of Pennsylvania; 8.4g W: 5749
8.5a-b C: PS2380; 8.5c W: 92W5720; 8.5d T: P6.43; 8.5e C: PS2380
8.6 TR: ZB3-21 & ZE3-22

8.7a-b C: PS2506; 8.7c W: 92W5725

8.8a C: D8-P265C; 8.8b W: 92W5674; 8.8c-d W: 92W5672

8.9 W: 92W5679

8.10a W: 92W5692; 8.10b W: M35968

8.11a Preserved specimen, source unknown; 8.11b C: PS2250

8.14 W: 92W6567

8.15 T: P6.82

8.16 W: 92W5793

8.17 W: 68W0819; W: 92W5723

8.18 Specimen provided by Academy of Health Sciences, Ft. Sam Houston

8.19 C: PS2180; W: 92W5673

8.20 W: 92W5823

8.21 Eggs isolated from raccoon feces found in Golden Gate Park, San Francisco, by Mae Ling Mak

8.22 W: 92W5693

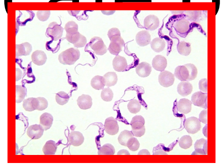
8.23a-b W: 92W6004;

How to use this CD

- The icon 🗋 (in the lower left of a photograph) takes you to a text page describing the picture.
- The icons ⏮ ▶ ◀ ↺ (in the lower right) take you to
  - the beginning of the chapter
  - the next photo in the series
  - the prior photo in the series
  - the last page you visited

10 µm

- This symbol shows the approximate scale of the picture:
- A miniature picture takes you from the text page back to the picture associated with it.



- The ico 🟩 on the lower left of the text page takes you to a diagram of the life cycle of the parasite.
- Hypertext links are shown in red.
- **I** takes you to the Index. **T** to the Table of Contents.
- Use th ☒ icon on the Internet Explorer toolbar to exit the Atlas.
- For the best image:
  - Choose “full screen” view (F11)
  - Hide the Windows Taskbar (Start/Settings/Taskbar & Start Menu/Auto hide)

T ◁ ▷

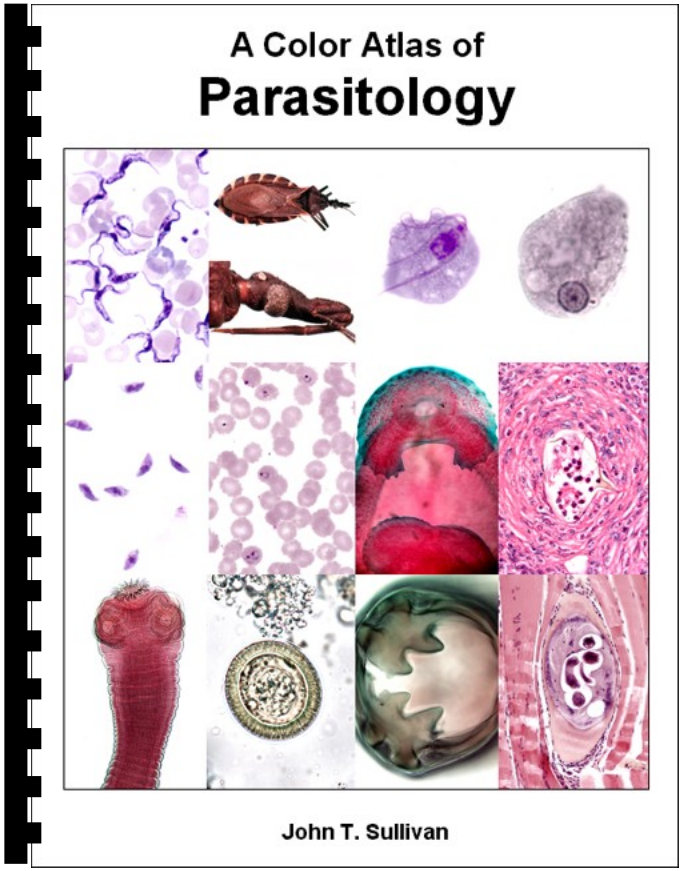
Unlike navigation on the Internet, this program “remembers” only the last slide you visited. Therefore, if you follow a text hyperlink to a photo slide, you can return to the text slide with the icon. However, if you visit the text page for that photo, you will not be able to immediately go back to the original text slide, unless a “hard” return link has been provided in the text or separately, e.g.,

- back to *Trypanosoma b. gambiense*

If no return link is available, or if you get lost, then return to the chapter table of contents with the icon or to the book table of contents with the icon. Alternatively, you can retrace your steps with the back arrow on the Internet Explorer toolbar.

All of the photographs were taken by the author. Most of the photos in earlier editions of the atlas were made with a Sony DXC-970 video camera, but nearly all of these have been replaced with higher resolution images taken with a Polaroid DMC Ie or Diagnostic Instruments Insight digital camera. The adult *Ascaris lumbricoides* and *Dirofilaria immitis* were photographed with a hand-held Olympus digital camera. Images were saved as uncompressed TIFF files, and were modified (contrast, sharpness, etc.) using camera software and Adobe PhotoDeluxe. Multiple images then were inserted into Microsoft PowerPoint slides, and the slides were captured as bitmap files with a screen capture program. Slides were resized to 800 x 600, and re-inserted into PowerPoint. The rather large (190 MB) file was then saved in HTML for ease of use. The PARASITES.htm file can be opened with

A color printed version of the photographs and text in chapters 1-8 of this CD also is available. For more information, please visit: http://www.geocities.com/parasiteatlas/parasites.html



A Color Atlas of

Parasitology

John T. Sullivan

References

Most of the textual information in this CD has been obtained from the following:

Ash, L.R. and Orihel, T.C. 1990. *Atlas of Human Parasitology*. 3rd ed. ASCP Press.

Roberts, L.S. and Janovy, J.J. Jr. 2000. Gerald D. Schmidt & Larry S. Roberts' *Foundations of Parasitology*. 6th ed. McGraw-Hill Publishers.

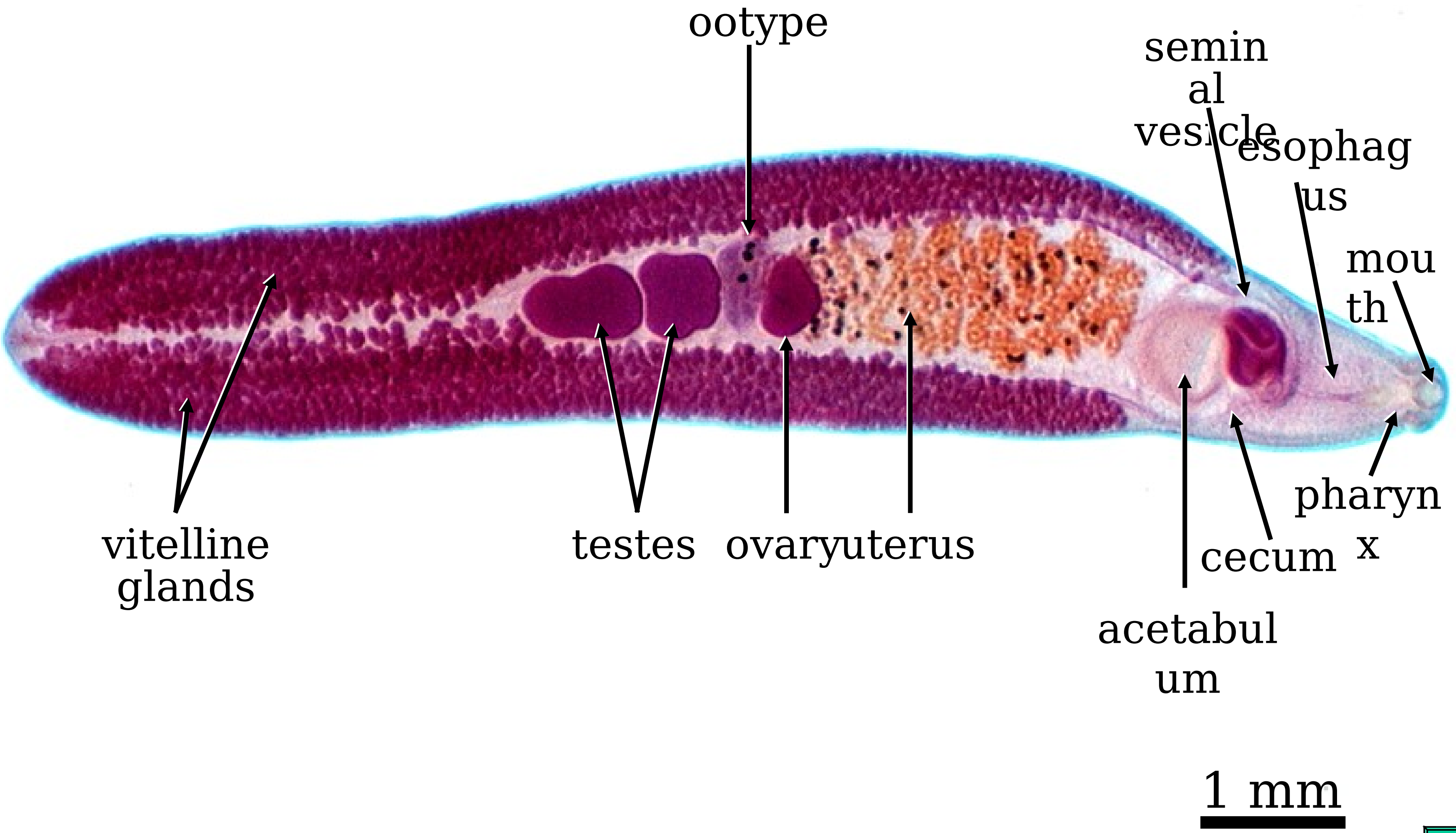
For the following specific topics, additional sources were consulted:

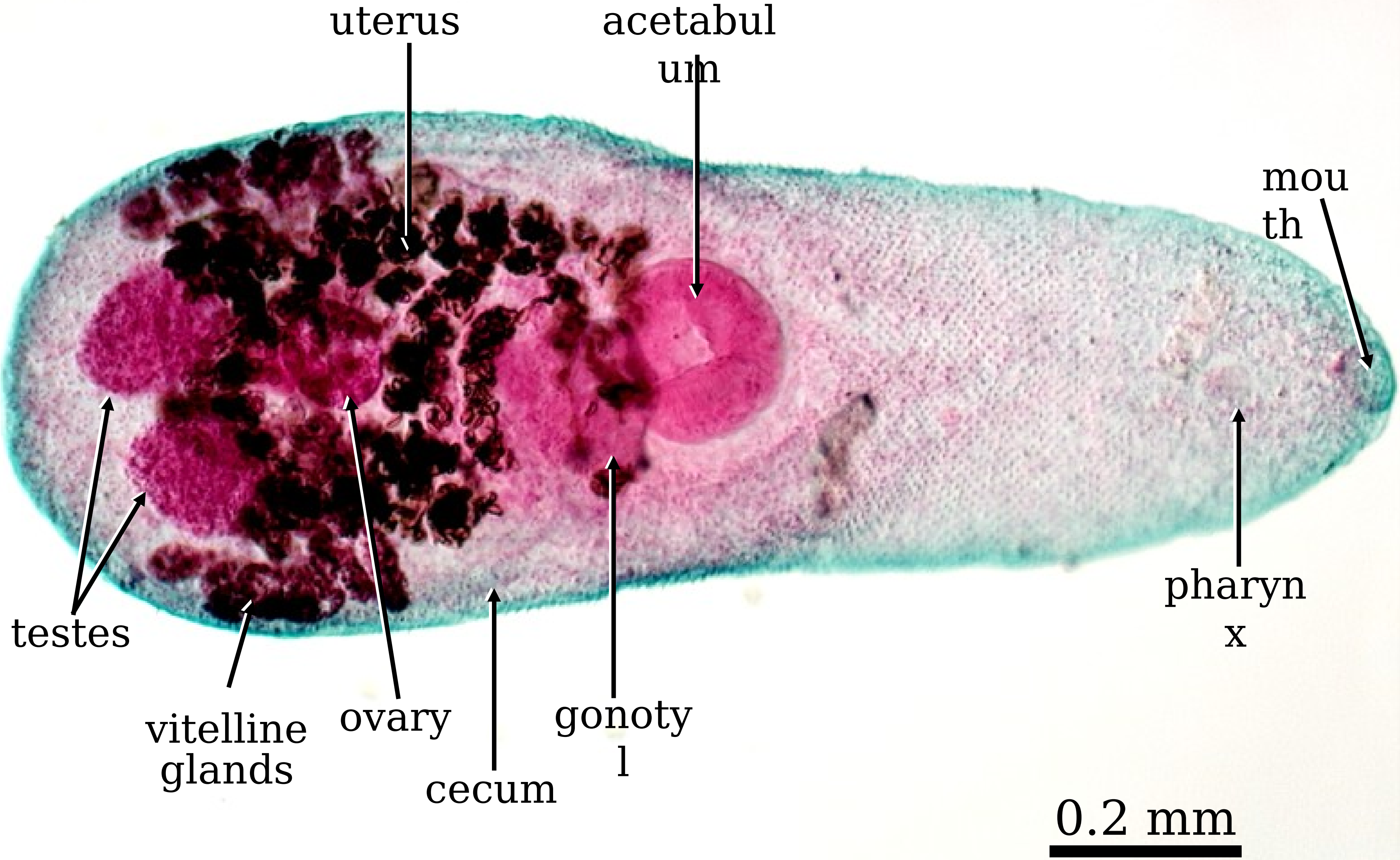
Diagnosis of malaria parasites

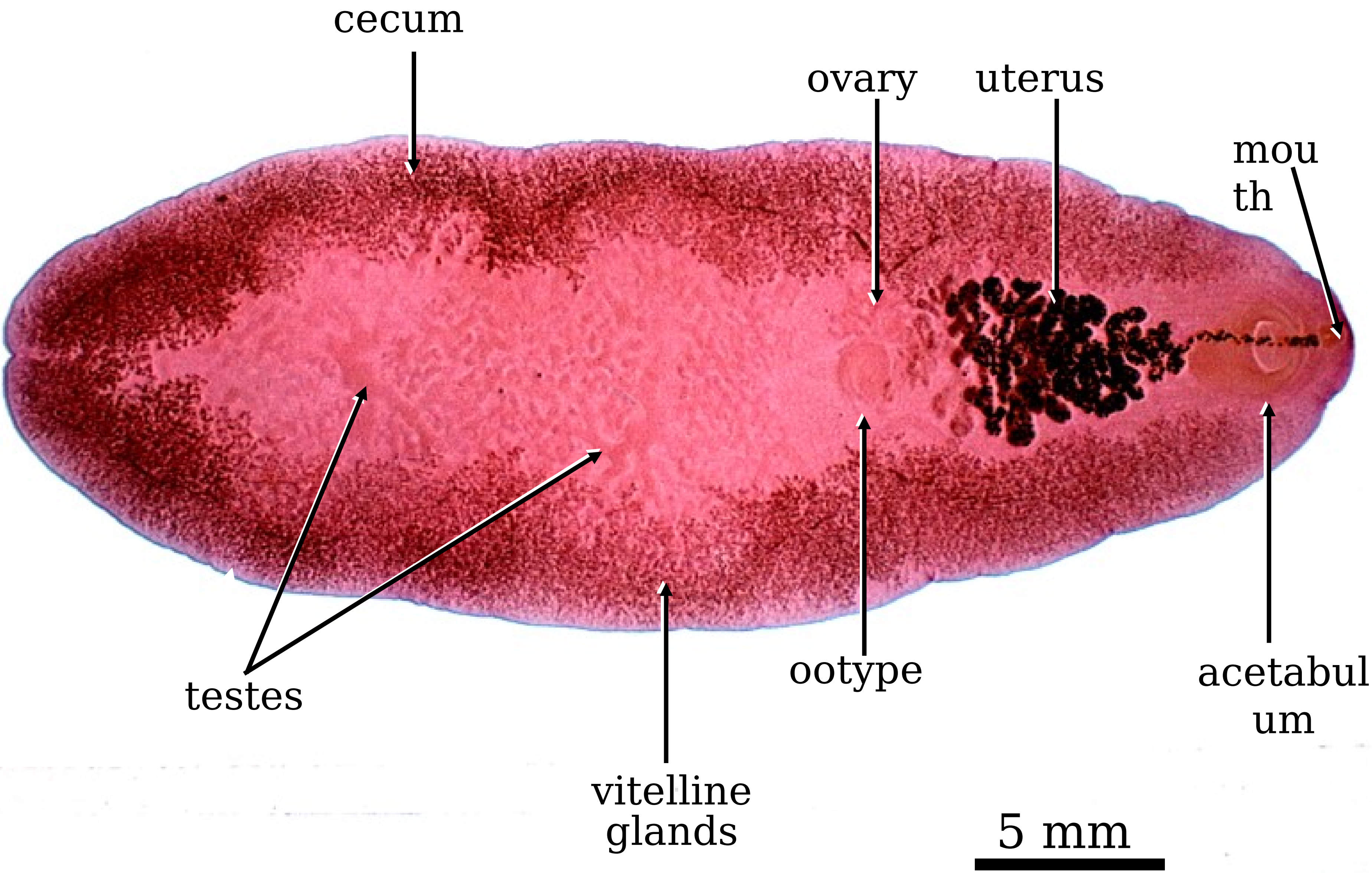
Cuviello, P.V. 1995. Malaria: Part II. AMT Events CE Supplement, April.

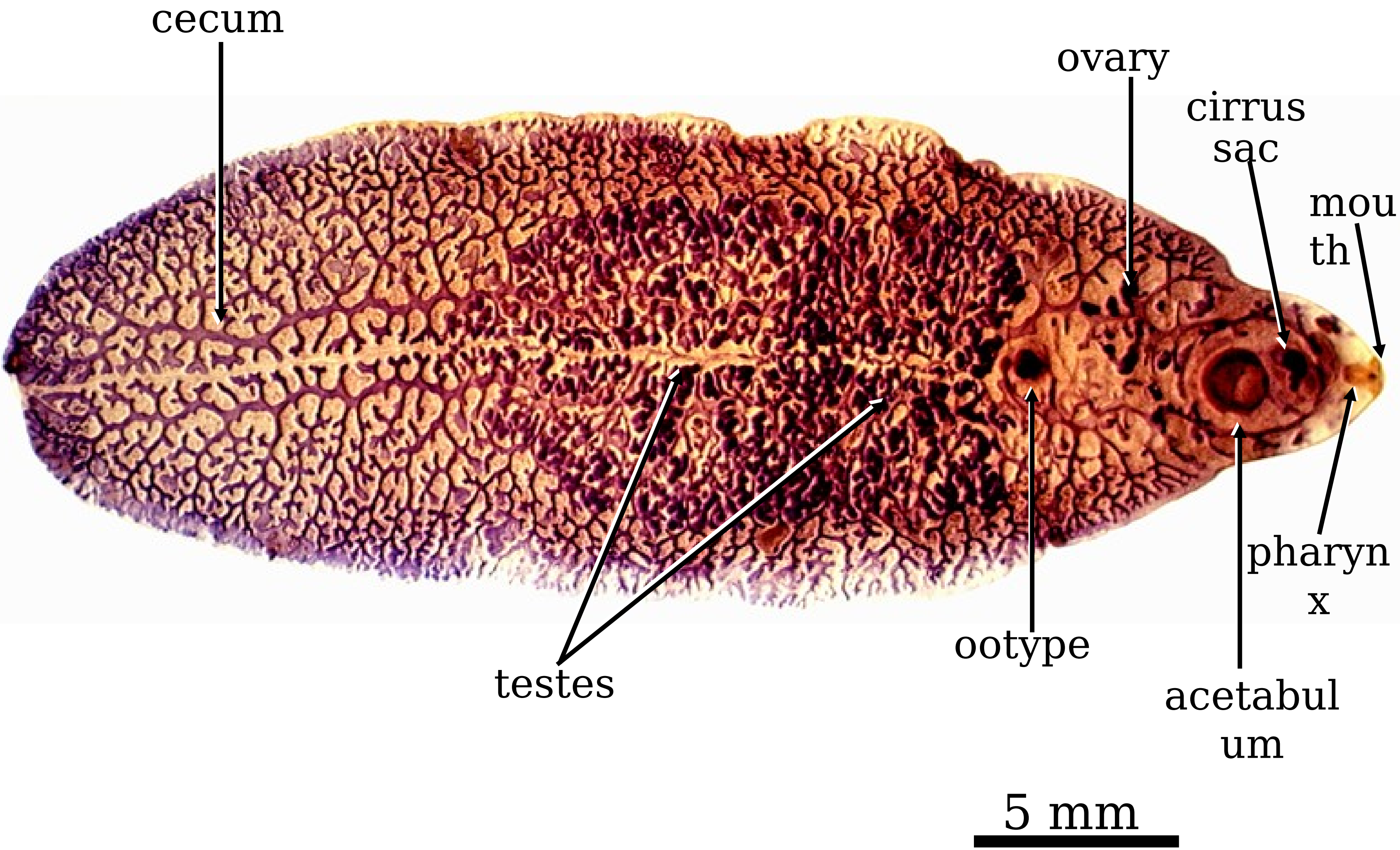
105-110.

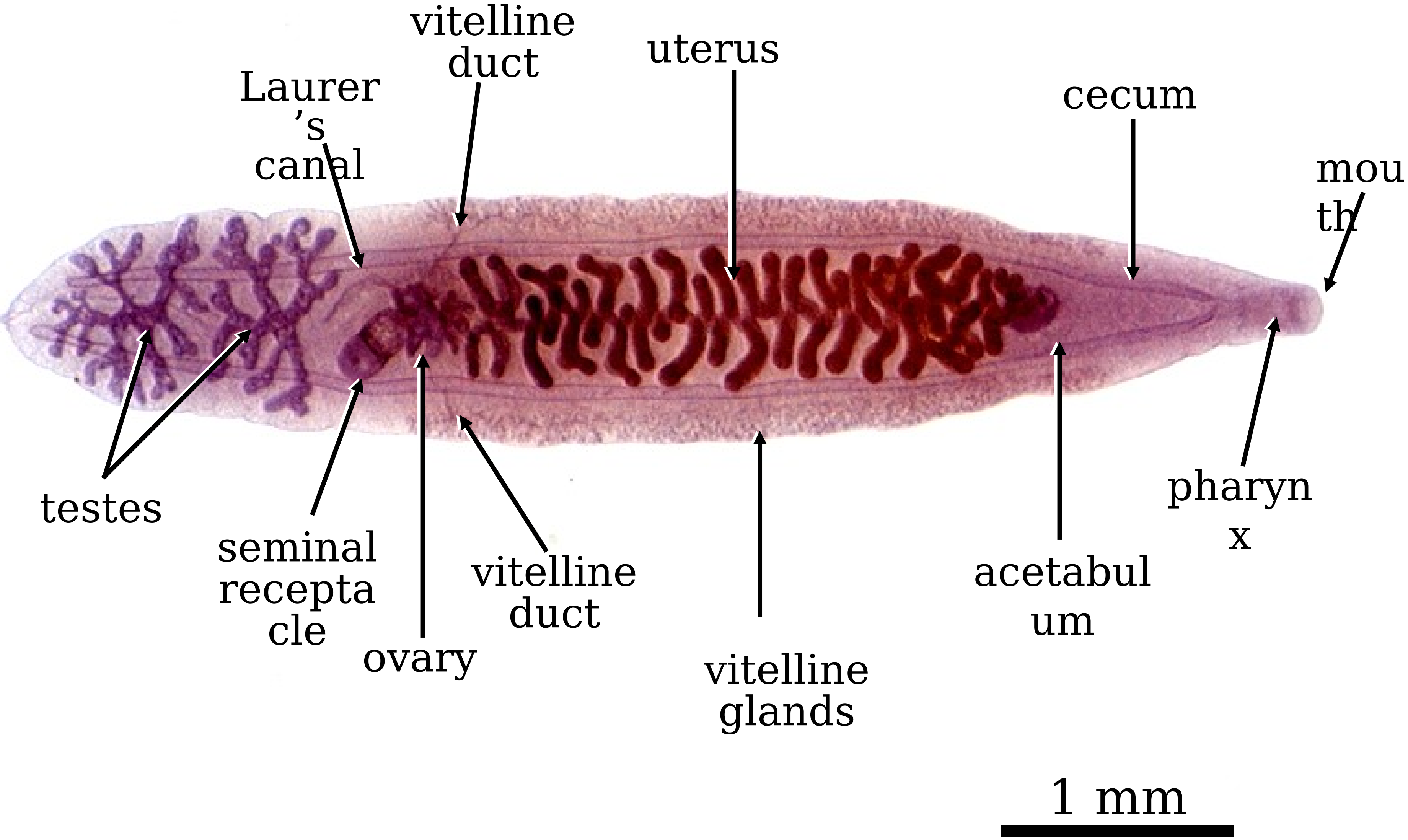
Tissue sporozoans

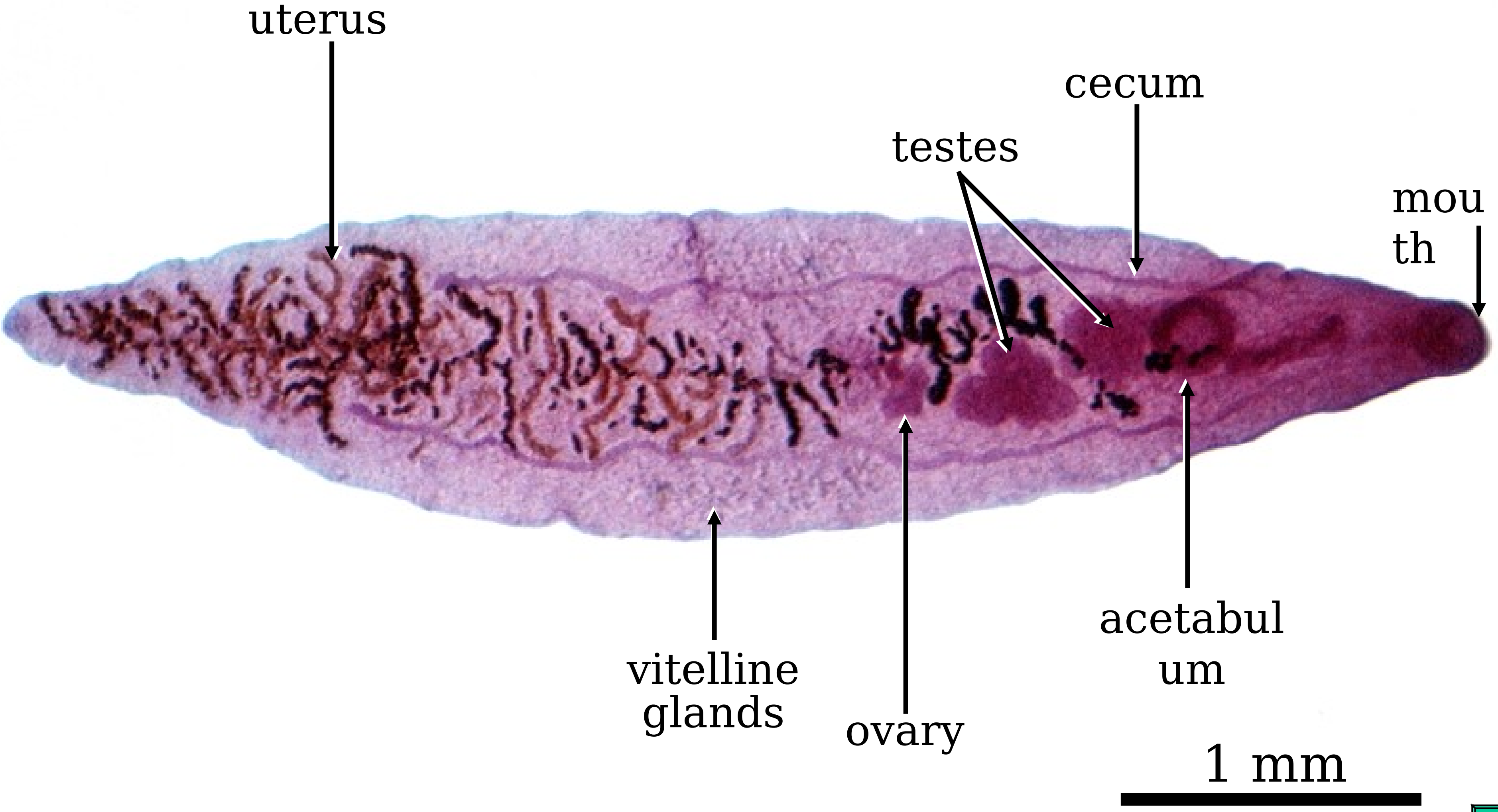

ootype
seminal vesicle
esophagus
mouth
vitelline glands
testes
ovary
uterus
pharynx
cecum
acetabulum
1 mm

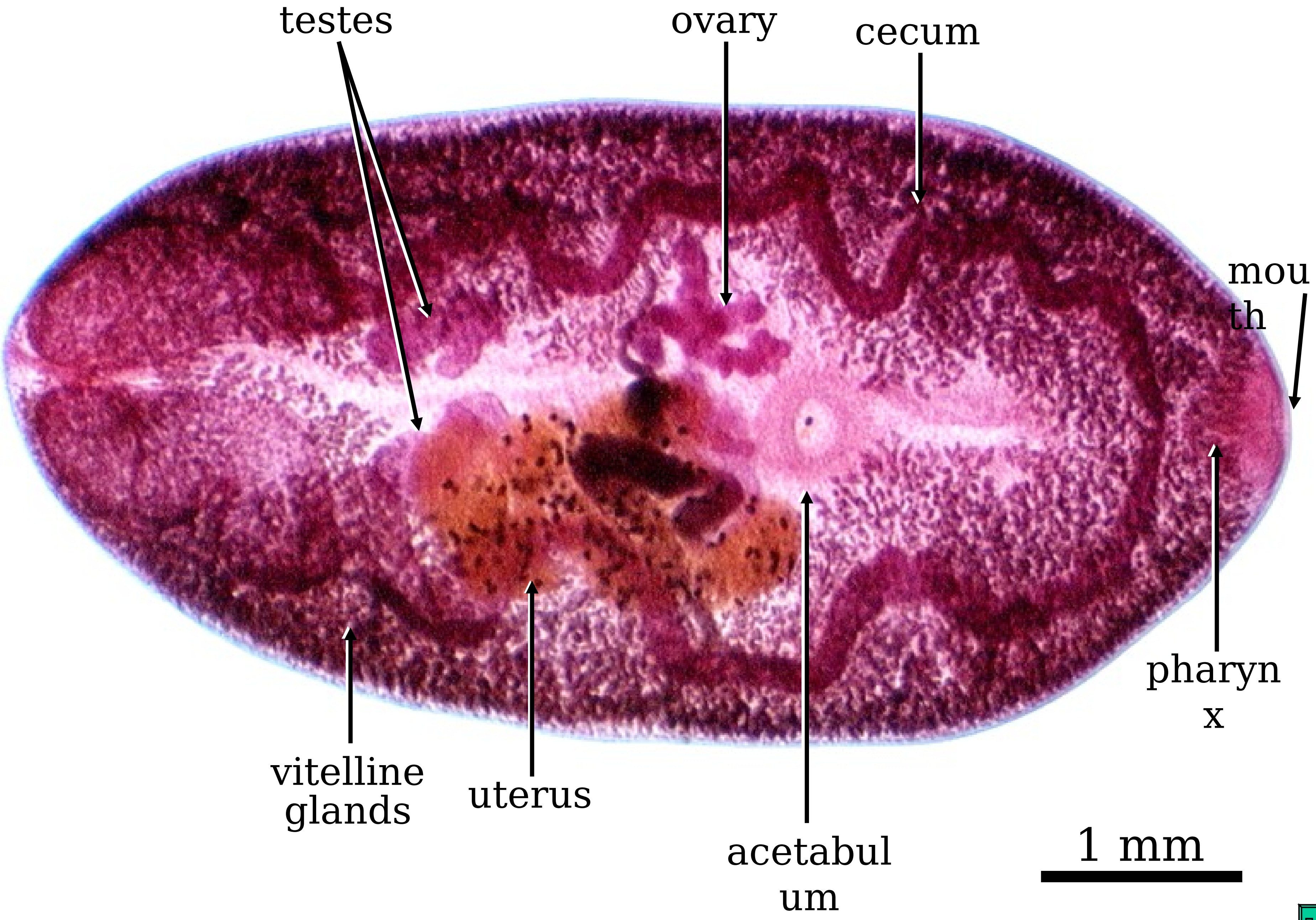

uterus
acetabulum
mouth
testes
vitelline glands
ovary
cecum
gonotyl
pharynx
0.2 mm

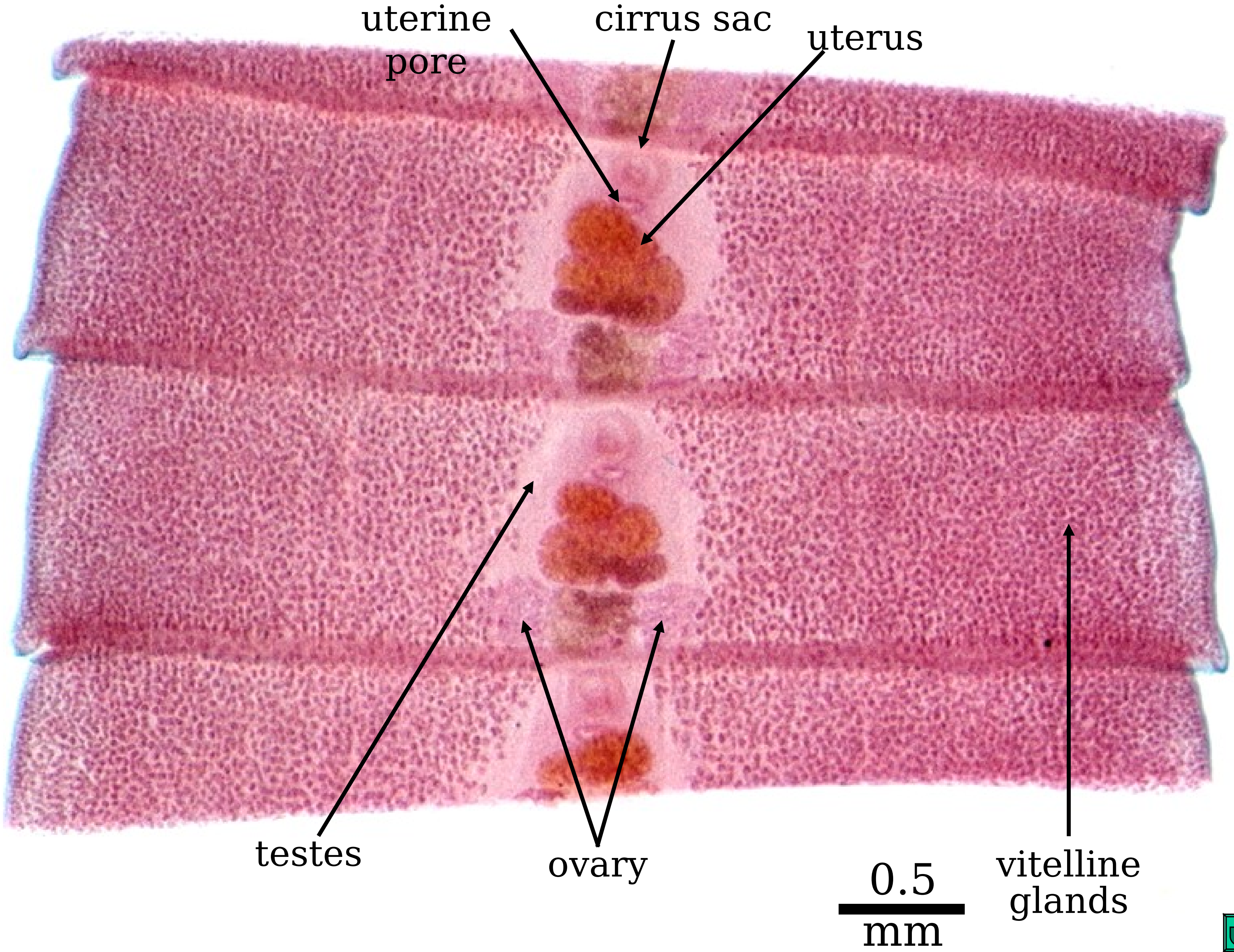

cecum
ovary
uterus
mouth
testes
vitelline glands
ootype
acetabulum
5 mm

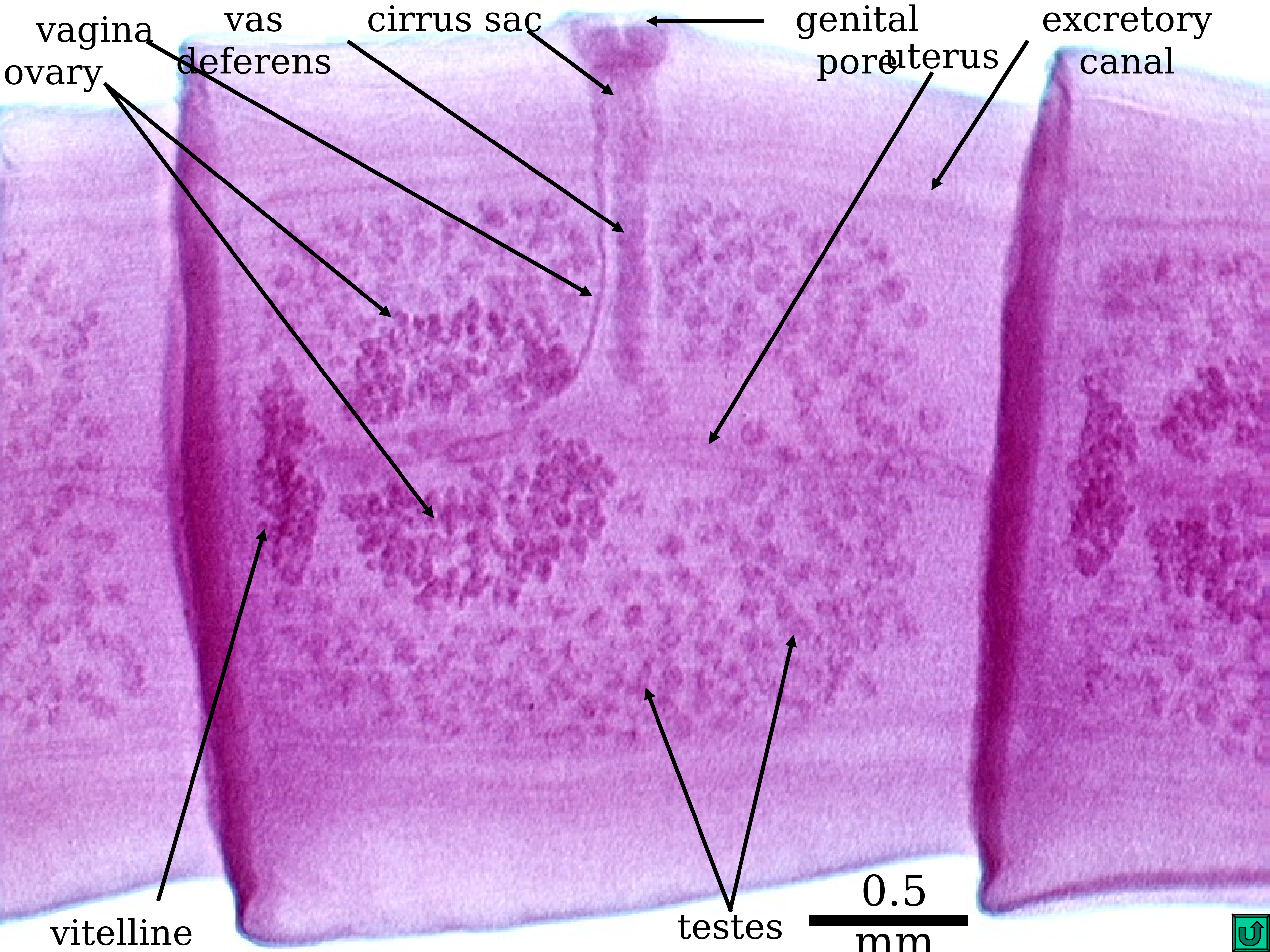

cecum
ovary
cirrus sac
mouth
testes
ootype
pharynx
acetabulum
5 mm

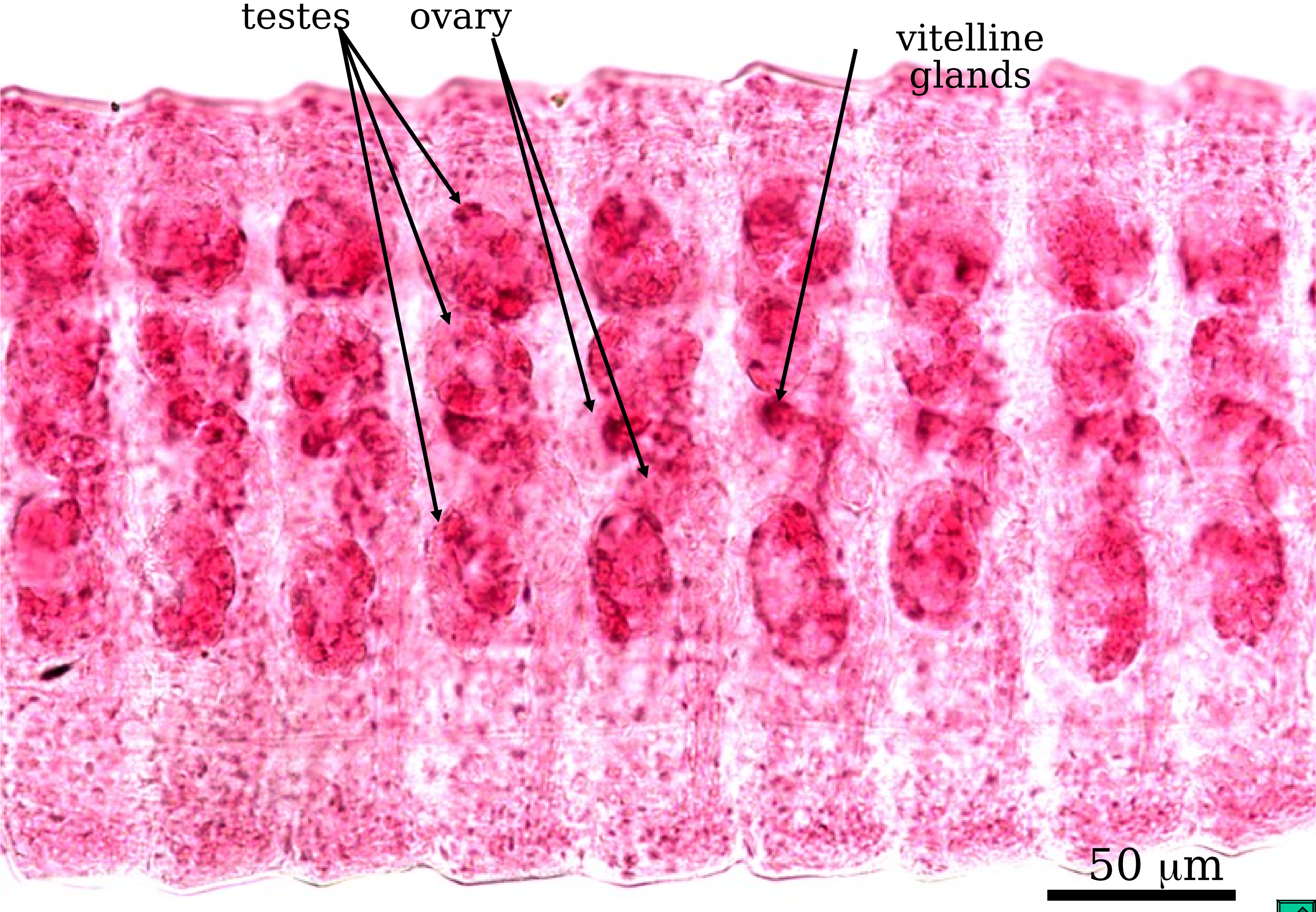

vitelline duct
uterus
Laurer's canal
cecum
mouth
testes
seminal receptacle
ovary
vitelline duct
vitelline glands
acetabulum
pharynx
1 mm

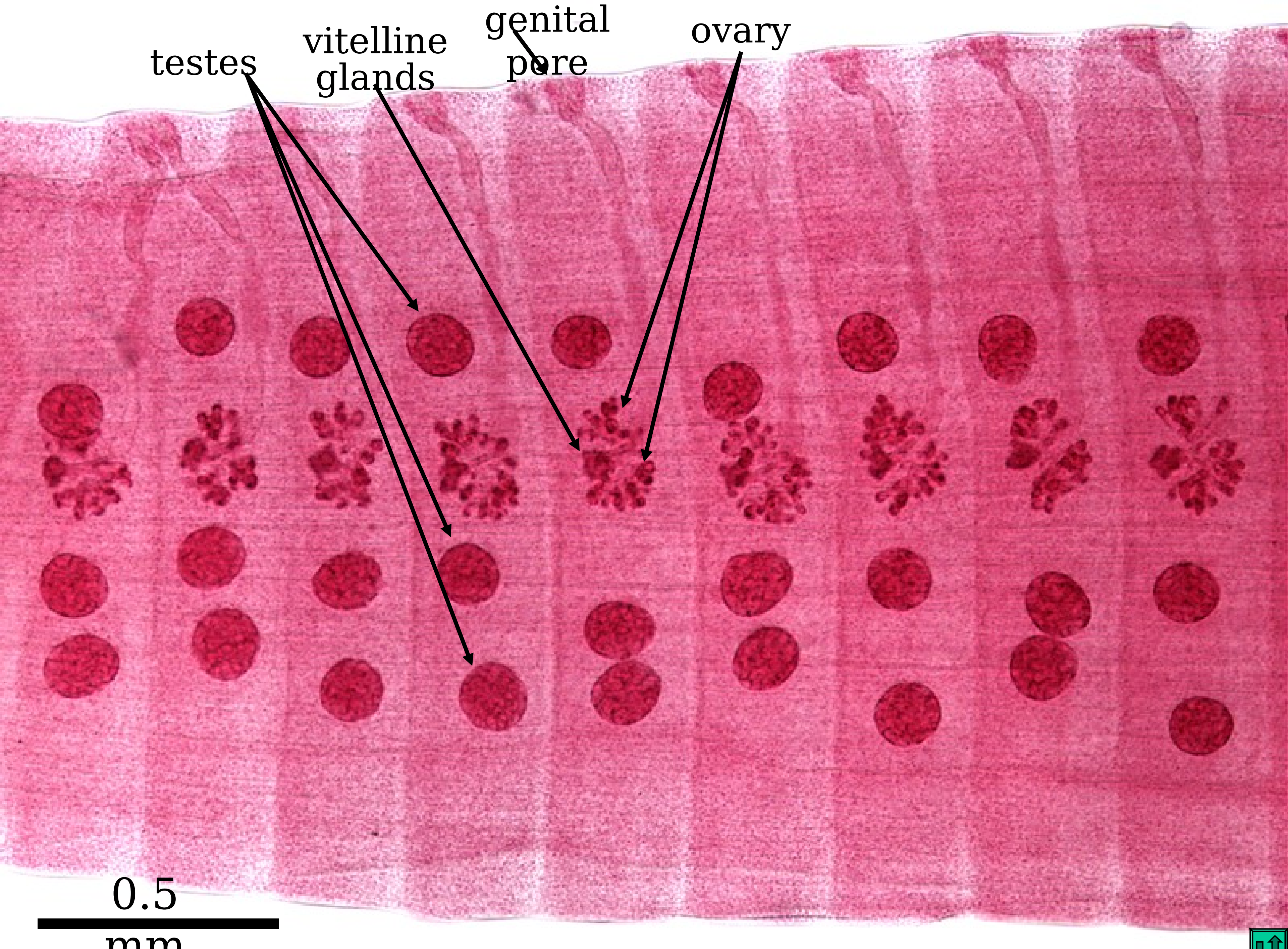

uterus
cecum
testes
mou
th
acetabul
um
vitelline
glands
ovary
1 mm

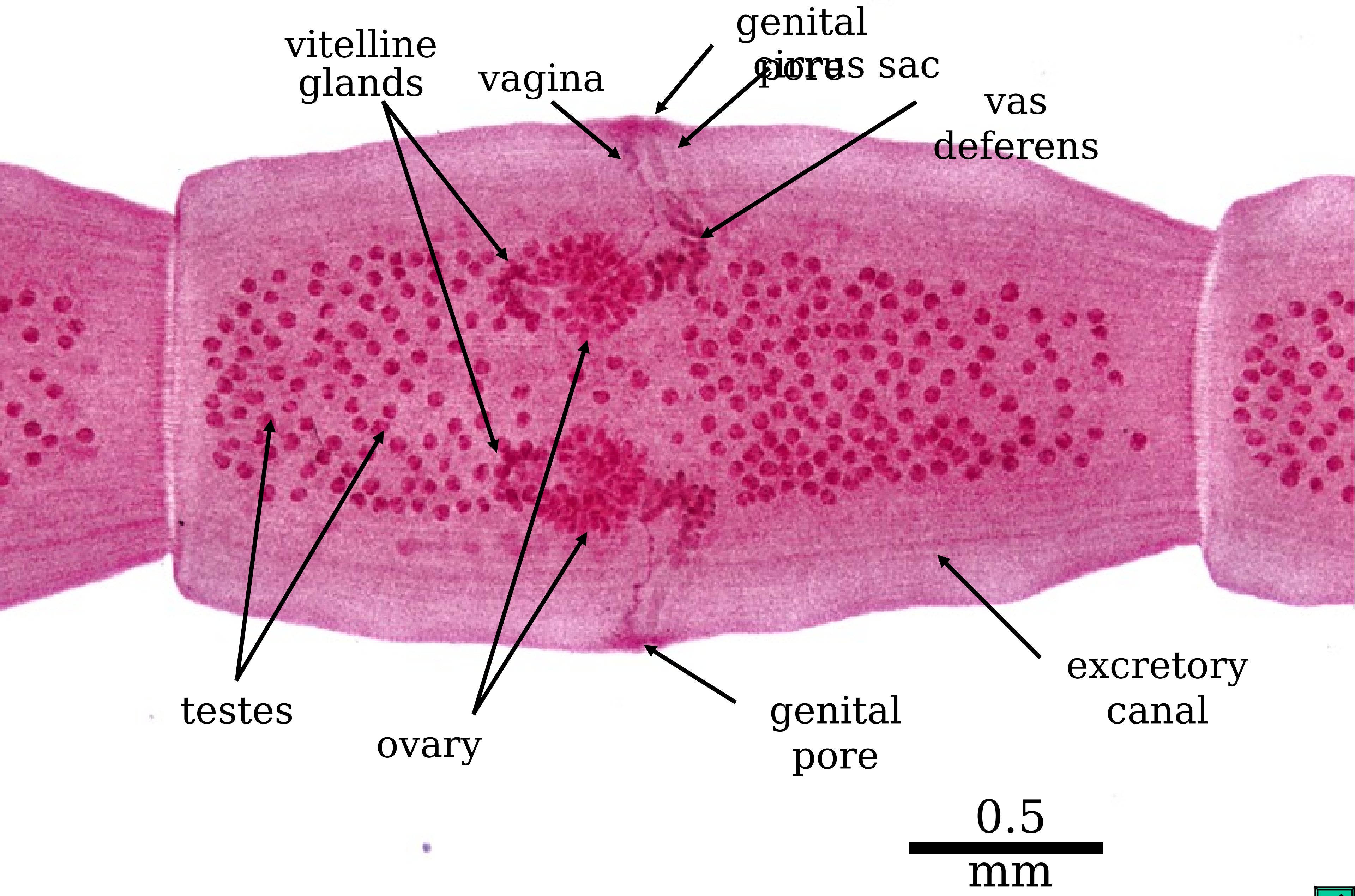

testes
ovary
cecum
mouth
pharynx
acetabulum
uterus
vitelline glands
1 mm


uterine pore
cirrus sac
uterus
testes
ovary
0.5 mm
vitelline glands


vagina
vas deferens
cirrus sac
genital pore
excretory canal
ovary
uterus
vitelline
testes
0.5 mm


testes
ovary
vitelline glands
50 μm


testes
vitelline glands
genital pore
ovary
0.5 mm


vitelline glands
vagina
genital pore
cirrus sac
vas deferens
testes
ovary
genital pore
excretory canal
0.5 mm